



## **Adult Escapement Monitoring Program Summary 2006-2007**



prepared for California Department of Fish and Game  
Contract P0560415

**ON THE COVER**

Large adult male coho (*Oncorhynchus kisutch*) working his way up a riffle during the 2006-2007 spawner season.  
Photograph by: Casey Del Real

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# **Adult Escapement Monitoring Program Summary**

## ***2006-2007***

Natural Resource Report NPS/SFAN/NRTR—2007-XXX

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## Introduction

Olema Creek, Redwood Creek, and Pine Gulch Creek are the largest undammed watersheds in coastal Marin County, California and are important streams for endangered coho salmon (*Oncorhynchus kisutch*) and threatened steelhead trout (*O. mykiss*) within the central California coast Evolutionarily Significant Unit (CCCESU). The National Park Service (NPS) has conducted adult escapement surveys in Marin County watersheds since 1994. NPS results show that these watersheds have supported annual runs of coho ranging from less than 10 to more than 200 individuals. This report presents the summary information of adult escapement results for the 2006-2007 spawning season for Olema Creek, Pine Gulch, Redwood Creek, and Cheda Creek.

Olema and Cheda Creeks show the pattern of two strong year classes SY 2004-05 and 2006-07 (Year Class 1 & 2) and one weak year class, SY 2005-06 (Year Class 3). While Redwood Creek contains only one strong year class SY 2004-05 (Year Class 2), one moderate year class that may be in decline, SY 2006-07 (Year Class 1), and one weak year class, SY 2005-06 (Year Class 3). In Redwood, Pine Gulch and Olema Creeks the last two years, SY 2006-07 and SY 2005-06, represent reduced escapement results from previous year classes for all creeks surveyed. We surmise that the strongest year class prior to the 1997-98 ENSO event, Year Class 3, was severely impacted as fish attempted to overwinter during the El Nino winter. On Pine Gulch population and detection levels are still too low to make inferences on year class trends.

From our observations, the 2006-2007 coho salmon represented a moderate return for the cohort based on previous year class observations. January was a very dry month and had the direct effect of considerably reducing spawning activity. Not only did this reduced creek flows for spawning activity but also jeopardized redds that were constructed in the tributaries and in the mainstem of Olema and Redwood creeks.

The Olema Creek mainstem experienced a 25% decline in coho redds for the 2006-2007 year class compared to 2003-2004. John West Fork, the largest tributary to Olema Creek, showed a 28% increase in total redd production from the previous year class. Thus total Olema Creek watershed redd numbers, which takes into account John West Fork, declined by 13%. Redwood Creek mainstem had a 51% decline in total coho redd production from the previous year class. Redwood Creek had the lowest observed coho spawning activity when compared to previous data for this year class. On Pine Gulch, no spawning activity was observed. Cheda Creek, a tributary to Lagunitas Creek, showed a slight increase in redd development along with an increase in returning adult coho spawners.

The patterns represented in our monitoring data suggest regional influences on the coho salmon escapement observed over the past decade. Overall coho escapement within Marin County watersheds has been trending upward since the 1997-98 ENSO event likely triggered by the Pacific Decadal Oscillation (PDO), shifting the dominant productivity from the Alaska Current to the California Current in the late 1990s. Between 1999-2004/05, all three coho year classes in Olema Creek and Redwood Creek have

shown a strong response to these changed ocean productivity patterns. This upward trend is also documented in the return of coho salmon to the Pine Gulch Creek watershed in winter 2000-2001.

This research is conducted under the Endangered Species Act Section 10 Permit #1046 Modification 2 authorization managed by NOAA - Fisheries. Funding to support monitoring activities was provided through the National Park Service - San Francisco Area Network Inventory and Monitoring Program and the California Department of Fish and Game Fisheries Restoration Grant Program Contract P0560415.

## Background and Objectives

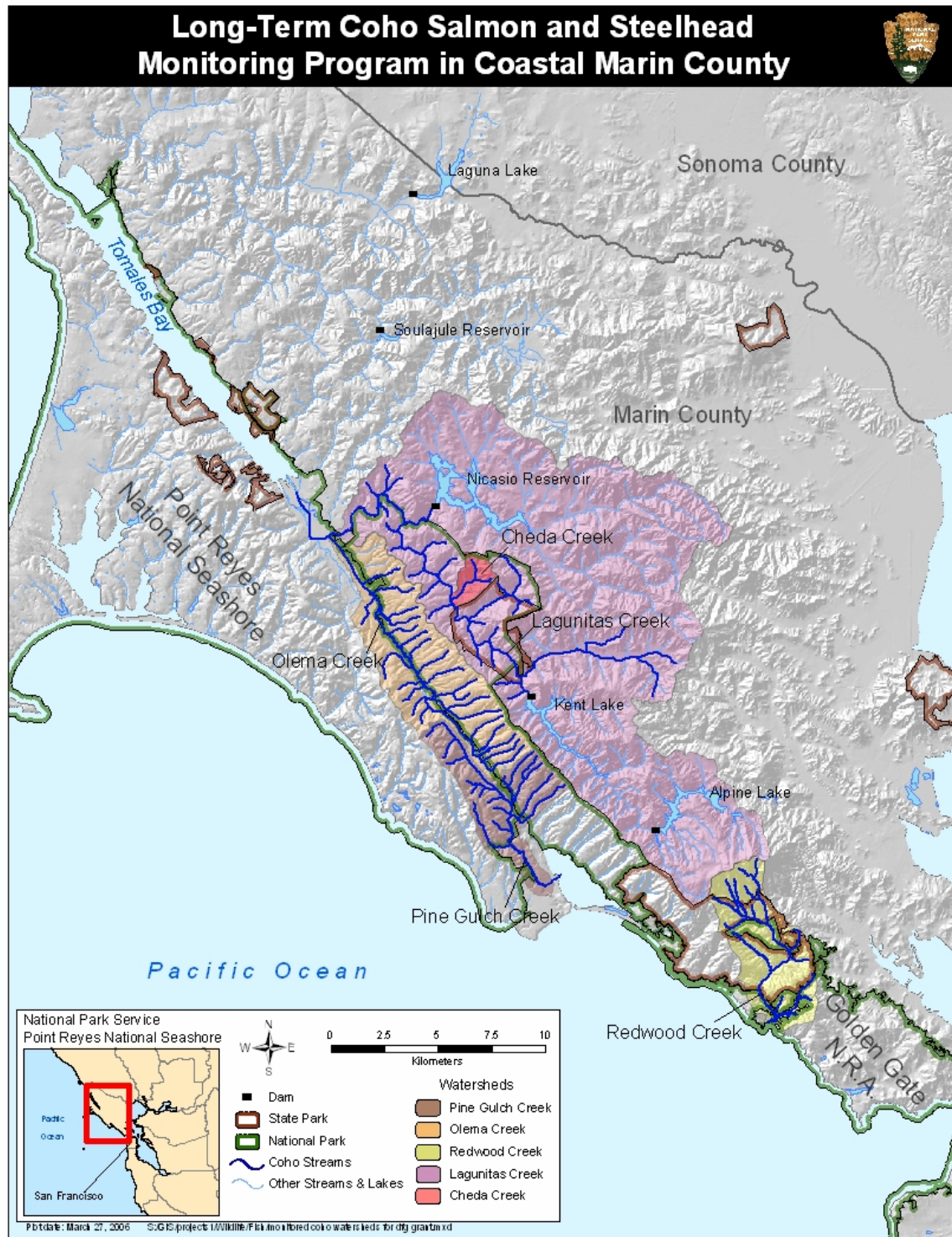
Annually, spawner surveys are conducted in watersheds within and adjacent to SFAN Park units, including Point Reyes National Seashore (PORE), Golden Gate National Recreation Area (GOGA), and Muir Woods National Monument (MUWO). These surveys concentrate primarily on federally endangered coho salmon (*Oncorhynchus kisutch*) and federally threatened steelhead (*O. mykiss*). The watersheds within Coastal Marin County and summarized in this report, including Olema Creek, Redwood Creek, and Pine Gulch Creek (Figure 1) are considered to support the most southerly stable populations of coho salmon.

The report summarizes the 2006-07 spawning results for the monitored watersheds. Surveys are typically conducted weekly between December and February, but are highly dependent upon the precipitation accumulations during the season. Redds, live fish, and carcasses are counted in an attempt to better understand trends in abundance and distribution.

## Introduction and History

As the return of adult salmon to their natal streams to spawn is of great interest to the local community, there is a long history of adult spawner observations in the area. MUWO staff began recording spawning fish observations on portions of Redwood Creek in 1944. Infrequent surveys were performed by the California Department of Fish and Game and local visitors from 1969 to 1986. In 1993, GOGA and PORE biologists initiated more detailed surveys on Redwood Creek and assisted the Tomales Bay Association (TBA) with surveys on Olema Creek. The first complete surveys of Olema Creek were undertaken in the winter of 1995-96 by the TBA and PORE. Systematic monitoring within the SFAN watersheds was initiated beginning in SY 1996-1997.

The Coho and Steelhead Restoration Project (CSRP) was initiated in 1997 and continued the work began by the TBA and previous NPS biologists with comprehensive surveys of Olema Creek, Redwood Creek, Cheda Creek (a Lagunitas Creek tributary) and Devil's Gulch (a Lagunitas Creek tributary) in the winter of 1997. To increase the value of the information collected during spawning surveys, and enable comparison of data from year to year, the CSRP began efforts to standardize methods and test different survey methodologies. Marin Municipal Water District (MMWD) took over Surveys on Devil's Gulch starting in the winter of 2000. Spawner surveys in Pine Gulch documented the return of coho during the winter of 2000-2001. In 2003, the fisheries monitoring efforts were incorporated into the San Francisco Bay Area Network (SFAN) Stream Aquatic Monitoring Program. Protocols to document field and analytical methods have been developed for the adult escapement monitoring efforts (Ketcham et. al 2005a).



**Figure 1. Map of coho streams in Marin County.**

### **Watershed Background**

Olema Creek is the largest undammed watershed in coastal Marin County, California and an important stream for coho salmon and steelhead within the CCCESU. The 15.9 km

stream flows northwest through the Olema Valley, the landward expression of the San Andreas Fault Zone. It's confluence with Lagunitas Creek lies at the head of the ecologically significant Tomales Bay. Protected from development, the 14.5 square mile watershed is primarily contained within the boundaries of Point Reyes National Seashore and the Golden Gate National Recreation Area North District. The watershed provides habitat to four federally protected aquatic species (California freshwater shrimp – endangered; coho salmon – endangered; steelhead – threatened; California red-legged frog – threatened). Olema Creek is the focal point of hydrologic, water quality, and fisheries monitoring within Point Reyes National Seashore.

Redwood Creek is a 7.5 square mile coastal watershed in southern Marin County, California. Redwood Creek flows southwest from the flanks of Mt Tamalpais, through Muir Woods National Monument, discharging to the Pacific Ocean through Big Lagoon at Muir Beach, CA. Protected from development, the watershed is primarily contained within the boundaries of Mt Tamalpais State Park, Golden Gate National Recreation Area and Muir Woods. The watershed provides habitat to coho salmon – endangered; steelhead – threatened; and the California red-legged frog – threatened. Redwood Creek supports a genetically distinct sub-group of coho salmon (Garza and Gilbert-Horvath 2003) within the CCCESU.

Pine Gulch Creek drains a 7.5 square miles watershed in coastal Marin County, California, and is the primary freshwater input to Bolinas Lagoon. Pine Gulch Creek is located within the CCCESU where coho salmon and steelhead occur. The watershed supports a population of steelhead and it is generally accepted that it supported a native self-sustaining population of coho salmon into the 1970's. It is likely that the drought of the late 1970's coupled with in-stream damming during the same period severely depleted multiple year classes and led to unsuitable conditions for continued survival of the species within the Pine Gulch watershed. In 2001, NPS documented return of coho salmon to the watershed beginning with recovery of a coho carcass, and subsequent documentation of coho juveniles in the watershed the following summer (Brown and Ketcham 2002). Monitoring indicates that all three coho cohort year classes are represented within Pine Gulch Creek (Ketcham and Brown 2003).

Cheda Creek is a small but important tributary of the Lagunitas Creek watershed and provides critical habitat for steelhead trout and coho salmon. Past land-use within the Cheda Creek drainage has resulted in serious alterations to the natural hydrologic and riparian condition of the creek. These factors have negatively impacted salmonid populations, water quality, and the ability of the aquatic ecosystem to function properly. The construction of a fish passage structure in the fall of 2000 was part of an overall watershed restoration project initiated by the National Park Service (NPS) to restore the system to a more natural and sustainable condition.

This report summarizes the 2006-2007 spawner season on Redwood Creek, Olema Creek, Pine Gulch Creek, and Cheda Creek watersheds. Detailed results of previous years have been reported in previous documents.

## **Sampling Design and Methods**

NPS staff and trained volunteers conduct surveys each winter during the coho spawning season to quantify escapement and determine spawning density and distribution. Although surveys focus on coho, steelhead spawners and redds are observed and counted during the surveys. Surveys are spaced approximately every week, although storms and high stream flows often dictate less frequent surveys. Teams of two to four observers walk upstream through 2-4 km reaches, along creek margins and banks where possible, and look for live fish, carcasses, and redds. Live fish are identified to species and sex, and lengths are visually estimated. Carcasses are measured (fork length), identified to species and sex, and marked to prevent double counting. Carcass scales and tissue samples are collected for age and genetic analysis. Scale samples are only collected from fresh (both eyes are still clear) carcasses that have not been mauled by scavengers. Redds are measured and marked with flagging. Redd monitoring is targeted as they are stationary and can be monitored over time to determine spawning success. In northern California, a model has been developed to estimate spawning population based upon redd count and redd effort (Gallagher and Gallagher 2005). These estimates are derived from redd measurements currently collected through the monitoring protocol. The NPS plans to work with CDFG researchers to calibrate the model to monitoring in this area.

Particular care is taken not to disturb redds or actively spawning adults. Locations of all live fish, carcasses and redds are recorded in reference to permanent tags placed every 100 meters along each stream. The survey data is used to generate index values and minimum population estimates for the assessment of long term trends.

Coho typically return to spawn over a one to three-month period from November through January (weather dependent). As residence time on the spawning grounds is variable, live fish may be double counted during repeated surveys. Reported spawning escapement estimates are made using the Peak Live + Cumulative Dead (PLD) index. This index is derived by adding the peak number of live fish observed during a single survey to the number of carcasses recovered on or prior to that date. Carcass information is also used to calibrate observer length and sex estimates. Redd counts are used to describe spawning density and spatial distribution. Where survey frequency is adequate, reporting will include escapement estimates using the Area Under the Curve (AUC) method (Irvine et al. 1992).

### **Site selection**

Watersheds that are part of the adult escapement monitoring program include Olema, Pine Gulch, Redwood and Cheda Creek. These watersheds are primarily or wholly within the NPS legislative boundaries. Salmonids in these watersheds are not monitored by other entities, therefore collection of these watershed data are important for park managers. Spawner surveys have been conducted on many of these watersheds since the early to mid-1990s. Monitoring effort and protocols were standardized with the implementation of the CSRP in 1997.

## **Number and location of sampling sites**

### ***Olema Creek***

A large section of the mainstem of Olema Creek, 17.6 km, has been surveyed by the TBA and PORE staff and volunteers since 1993. The section is currently divided into 7 survey reaches starting one kilometer above the confluence with Lagunitas Creek and ending at the Highway 1 culvert at milepost 19.94. Reaches are delineated to facilitate sampling based on access, length, and the existence of permanent landmarks for reach boundaries (Figure 2). The existing seven reaches extend from:

1. One kilometer above the confluence with Lagunitas Creek to the Bear Valley Road Bridge in the town of Olema (1.6 km).
2. The Bear Valley Bridge to the confluence with Truttman Creek (3.2 km).
3. Truttman Creek to the horse trail crossing at the Stewart Ranch (2.6 km).
4. Stewart Ranch to the first Hwy. 1 bridge at Five Brooks (1.3 km).
5. Five Brooks to the abandoned Lime Kilns (2.8 km).
6. The Lime Kilns to the abandoned Randall ranch House (1.7 km).
7. The Randall House to the HWY. 1 culvert at milepost 19.94 (4.1 km).





In addition to the mainstem of Olema Creek, surveys are often conducted on some of the larger tributaries. Most tributary surveys conducted in the past were intended only to establish presence or absence of spawning coho and reach lengths varied widely. At present, complete surveys are conducted for the tributaries as personnel and flow



conditions allow, based on order of priority. For each tributary, survey reaches start at the mouth and generally continue upstream as long as no passage barriers exist. The tributaries, many of them unnamed on U.S. Geological Survey (USGS) 7.5 minute maps, are named in Figure 1.2 and listed in order from downstream to upstream:

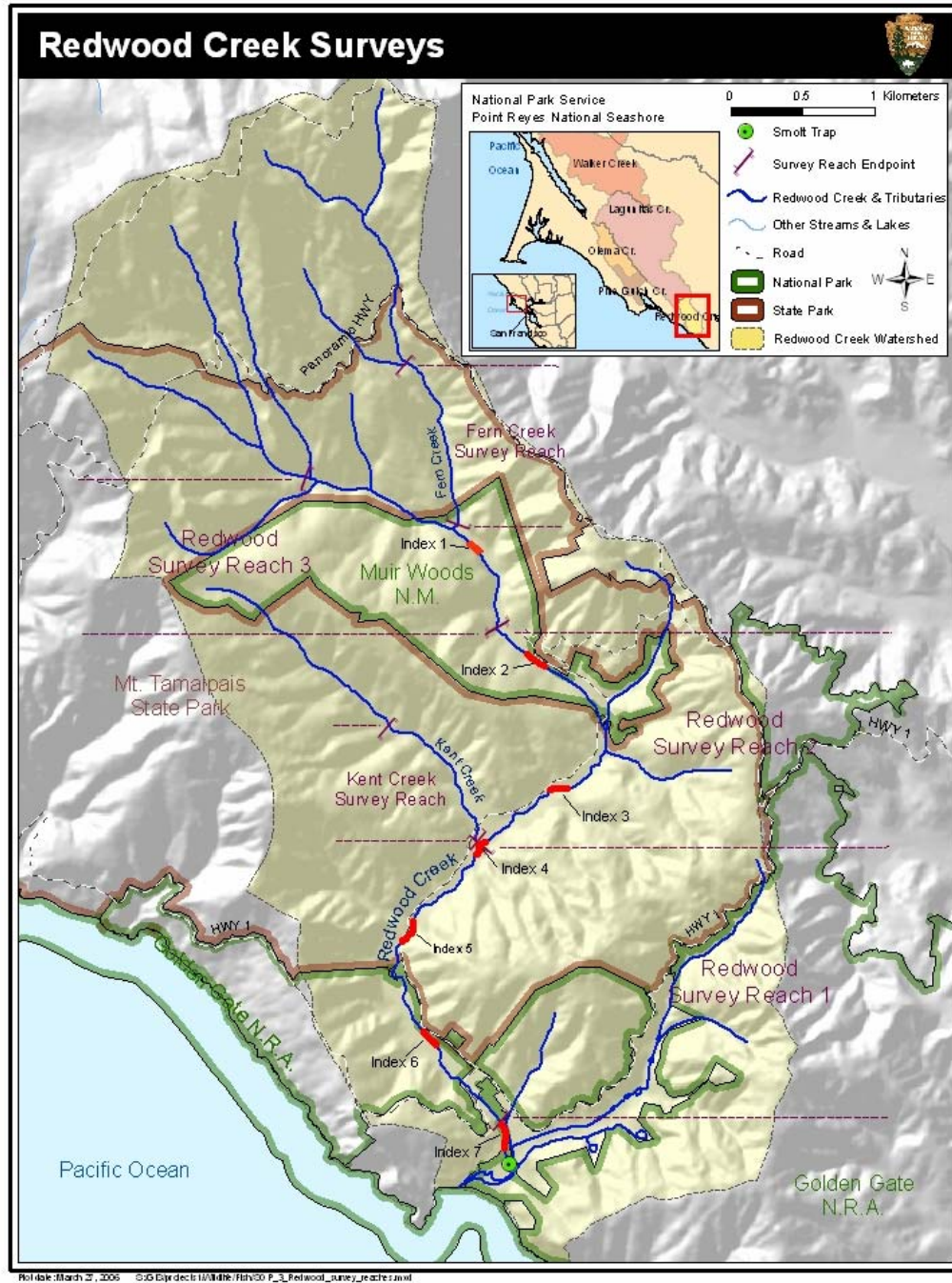
1. Quarry Gulch located close to the Olema Cemetery 4.1 km above the mouth of Olema Creek at Hwy. 1 milepost 25.35.
2. Boundary Gulch located 8.3 km above the mouth of Olema Creek at Hwy. 1 milepost 24.30.
3. Horse Camp Gulch located 9.6 km above the mouth of Olema Creek at Hwy. 1 milepost 23.26.
4. Giacomini Gulch located 10.8 km above the mouth of Olema Creek at Hwy. 1 milepost 22.78.
5. John West Fork located 10.9 km above the mouth of Olema Creek at Hwy. 1 milepost 22.67. (survey reach from trib mouth to 2 km upstream)

### ***Redwood Creek***

Since 1994, the NPS has conducted annual surveys along a 6.7 km section of the mainstem of Redwood Creek (Figure 3) between a point 140 m below the Pacific Way Bridge and around 500 m above Bridge 4 in Muir Woods. The section encompasses most of the stream length used by coho salmon. To facilitate sampling, the section is divided into three reaches;

1. Pacific Way Bridge to the Kent Creek confluence in Mt. Tamalpais State Park (2.7 km),
2. Kent Creek confluence to Bridge 1 in Muir Woods (2.4 km) and,
3. Bridge 1 to 500 m above Bridge 4 (1.6 km).

Portions of Fern and Kent Creeks, the two largest Redwood Creek tributaries, will also be sampled. The reach on Kent Creek extends from the confluence with Redwood Creek to a water fall, approximately 1 km upstream, that is impassable to migrating adults. The Fern Creek section has been surveyed since 1994 and extends between the Redwood Creek confluence and a series of steep cascades 1 km upstream.



**Figure 3. Redwood Creek Spawner Survey Reach Map**

***Pine Gulch Creek***

Since 1997, the NPS has conducted surveys along a 9 km section of the mainstem of Pine Gulch Creek. Coho salmon were first spotted during surveys in the winter of 2000-2001. Due to private property access issues and the nature of the watershed, the survey reaches are longer than normal (Figure 4). This requires a solid day to conduct the survey with two teams.

The spawner surveys start at the Olema-Bolinas Road Bridge and extend upstream to at least the Teixeira Ranch. Complete surveys should extend up the mainstem to the Pacific Coast Learning Center/Hagmaier complex. The section encompasses most of the stream length that would be potentially used by coho salmon.

Currently sampled reaches include:

1. Olema-Bolinas Road Bridge to the Copper Mine Gulch confluence (6.0 km).
2. Copper Mine Gulch– Upstream beyond Teixeira to approximately monument marker 100 (3.5 km).



### ***Lagunitas Creek Watershed - Cheda Creek***

Lagunitas Creek and its tributaries (Nicasio Creek, San Geronimo Creek, Devil's Gulch, Cheda Creek, Bear Valley Creek, and Olema Creek) drain more than 230 square kilometers of western Marin County. The headwaters of the Lagunitas Creek mainstem lie within the 53,000 ha watershed lands administered by Marin Municipal Water District (MMWD). The mainstem originally totaled about 40 km of perennial stream draining the northern slope of Mt. Tamalpais, but was reduced by more than 50% by construction of Alpine Dam in 1918 and Peters Dam in 1953. Because neither dam has provision for fish passage, their construction resulted in permanent loss of the upper portion of the drainage to anadromous fish.

The portions of the Lagunitas drainage most significant for salmonids are under a number of ownerships. Approximately 12 km of the mainstem is bordered by NPS lands (north district Golden Gate National Recreation Area). A major tributary, San Geronimo Creek, flows through privately held land in San Geronimo Valley. Devil's Gulch lies almost entirely within Samuel P. Taylor State Park with its headwaters in NPS lands. Only one smaller tributary of Lagunitas Creek, Cheda Creek, lies entirely within GGNRA lands.

Cheda Creek (Figure 5), a Lagunitas Creek tributary, has been surveyed since 1996-97 to detect the presence or absence of coho. The NPS completed a fish passage project in the fall of 2000, coho salmon spawning in the upper part of the creek above the fish passage project site was detected in the 2004-05 spawning season. Approximately 1.3 km of stream is typically surveyed, including a 0.8 km reach below the fish passage improvement and 0.5 km reach above.





## Recommended frequency and timing of sampling

Sampling duration is driven by both streamflow and visibility conditions. In these unregulated watersheds, streamflows required to facilitate salmon access to the watersheds occur between November and January based on rainfall (see Table 14 and 20 for coho run timing in Olema and Redwood Creeks). The typical spawning season for coho is late November into early February, while steelhead typically show up to spawn between January and March. Within our unregulated watersheds, spawner response is concentrated around storm events related to flow or freshet events.

Based on female redd residency times, watersheds should be surveyed weekly to accurately capture redd timing (Burton et al. 2002; van den Berghe and Gross 1986). Surveys are confounded by environmental factors (stream discharge and turbidity), as well as scheduling around the holidays, and are often less frequent.

## Routine data summaries and statistical analyses to detect change

The analysis of spawner survey data is complicated by annual variability in environmental conditions and run characteristics. Accurate abundance estimates are difficult to generate without counting weirs or other intensive sampling techniques (Irvine et al. 1992). The NPS monitoring program is, nonetheless, interested in developing precise indices of abundance. In addition to cumulative redd counts, two techniques, Peak Live Plus cumulative Dead (PLD) and Area Under the Curve (AUC) are used to compute coho salmon escapement index values (Beidler and Nickelson 1980; Johnston et al. 1987). In addition to calculating the indices, we summarized the live fish, redd, carcass, and environmental data for each stream.

The PLD and AUC estimates provide different types of information. While the PLD index produces a minimum instantaneous estimate, the AUC method is used to calculate a total population estimate. The PLD index is computed as the name suggests. The peak number of live fish observed during a single day of the spawning season is added to the cumulative number of unmarked carcasses observed prior to that date. The AUC estimate is calculated using the total number of live fish observed during each survey and the average life of fish on the spawning grounds (residence time). Calculating the area under the curve created by plotting the live fish observations for each survey, produces a quantity termed total fish-days. The area under the escapement curve was given by:

$$AUC = 0.5 \{ \sum (t_i - t_{i-1}) (p_i + p_{i-1}) \}$$

where  $t_i$  is the number of days since the first fish entered the survey area and  $p_i$  is the total number of fish observed on the  $i$ th day (Irvine et al. 1992). Dividing the total number of fish days by the residence time gives the population estimate. As we did not estimate residence time, separate AUC estimates were computed using the range of values, 8 to 17 days, presented in the literature (Moring and Lantz 1975; Johnston et al. 1987; Irvine et al. 1992). Data collection typically stops after repeated surveys no longer indicate the presence of live coho. High flows often prevent staff from conducting surveys during

significant portions of some spawner seasons. If fish were observed during the last survey of the season, the last date used for calculating the AUC estimate was arbitrarily set at 10 days after the final survey date.

Because the necessary conditions for accurate AUC estimates are not always met, we also quantify spawning runs using the Peak Live + Cumulative Dead (PLD) index. This index is derived by adding the peak number of live fish observed during a single survey to the number of carcasses recovered on or prior to that date, and is considered a minimum count. Redd count and location is used to describe spawning density and spatial distribution.



## **2006-2007 Olema Creek Adult Coho Escapement Results**

Olema Creek watershed spawner survey information includes data collected on 11.6 kilometers of the mainstem of Olema Creek, primarily reaches 2-6, and John West Fork, a tributary to Olema (see Figure 2). In addition, spawner surveys were conducted on Quarry Gulch, Boundary Gulch, Horse Camp Creek, and Giacomini Creek. For analysis, escapement results within these drainages are treated separately.

December, with 7.64 inches of rain recorded in Bear Valley, turned out to be the most productive month for coho spawning activity this year. Unfortunately, January was a very dry month with only 1.09 inches of rain. This not only reduced creek flows for spawning but also jeopardized redds that were constructed in the tributaries and in the mainstem of Olema Creek. This had the direct effect of considerably reducing spawning activity.

A winter storm on December 9 brought 1.21 inches of rain initiating the entry of coho salmon to the Olema Creek watershed. Spawner surveys were delayed until December 18 on the mainstem of Olema due to flow and visibility constraints. In the Olema mainstem, two peak spawning activities were observed on December 18 with 58 live coho and on January 10 with 17 live coho observed. A total of 66 coho redds were distributed throughout the mainstem of Olema Creek. Peak spawning activity on John West Fork was observed on December 14 with 10 live adult coho and again on December 29 with 17 live coho. A total of 29 definite coho redds were identified distributed along John West Fork.

### **Survey Timing and Environmental Conditions**

Six surveys were conducted in Olema Creek between 21 November 2006 and 16 February 2007 (Table 1). The mean interval between surveys was fourteen days. Seven day rainfall totals during Julian week ranged from a low of 0 during Julian weeks 53 and 5 and a high of 5.54 during Julian week 6. Average water clarity at the time of surveys ranged from 52cm to 100cm. The onset of rainfall and subsequent higher flows appeared to be related to live fish observations (Figure 6).

**Table 1. Seven day total rainfall per Julian week, average water clarity, and the number of coho redds, coho carcasses, and live coho observed in 2006-07 on the Olema mainstem.**

Julian Week	Survey Date	Survey Reaches	Calendar Day	7 Day Rainfall during Julian Week (in)	Average Survey Water Clarity (cm)	Coho Redds	Coho Carcass	Live Coho
46	13 Nov 06			1.65				
47	21 Nov 06	1-3	325	0.14	70	0	0	0
48				1.16				
49				1.86				
50				2.65				
51	18 Dec 06	2-6	352	0.84	95	34	5	58
52				2.28				
53	31 Dec 06	2-6	365	0	88	20	12	43
1				0.67				
2	10 Jan 07	2-6	10	0.02	100	9	5	17
3				0.03				
4	24 Jan 07	2-6	24	0.37	100	3	4	3
5				0				
6				5.54				
7	16 Feb 07	2-6	47	0.68	52	0	1	0
8				2.59				

Reach 2: Bear Valley Bridge to the confluence with Truttman Creek (3.2 km).

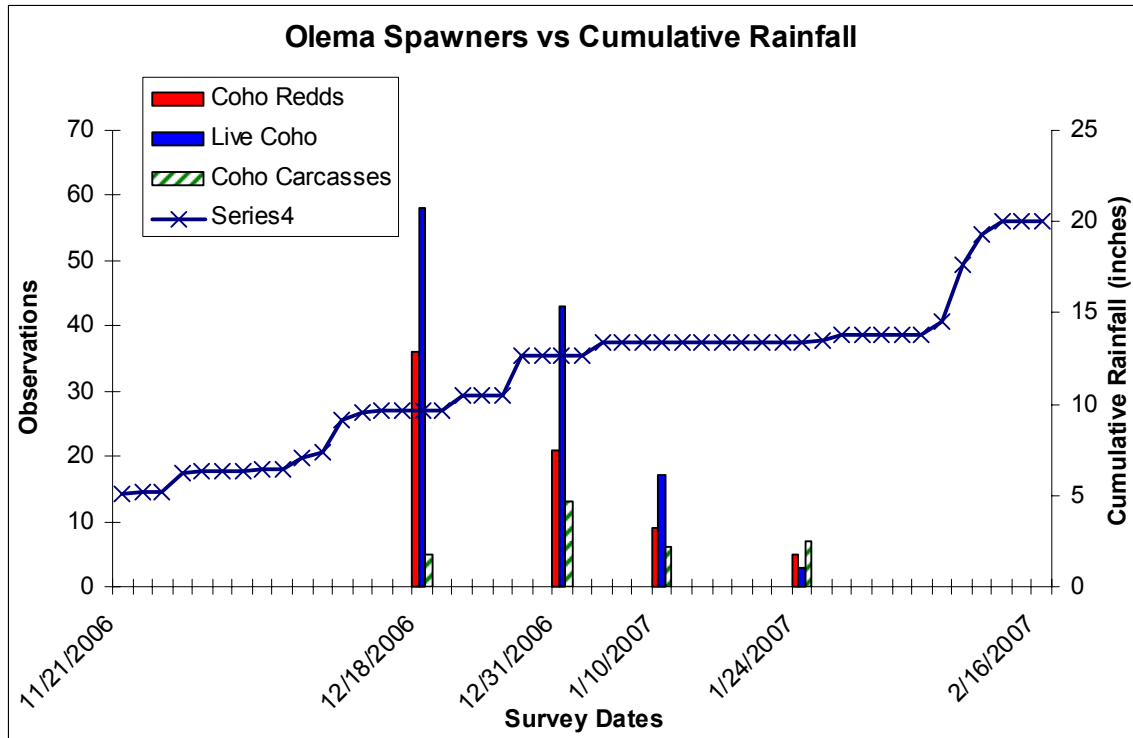
Reach 3: Truttman Creek to the Davis-Boucher Creek confluence at the Stewart Ranch (2.6 km).

Reach 4: Stewart Ranch to the State Route 1 bridge at Five Brooks (1.3km).

Reach 5: Five Brooks to the abandoned Lime Kilns (2.8 km).

Reach 6: The Lime Kilns to the abandoned Randall ranch house (1.7 km).

Reach 7: The abandoned Randall ranch house to the Hwy. 1 culvert at milepost 19.94 (4.1 km).



**Figure 6. Representation of rainfall totals and coho adult escapement survey results on Olema Creek Mainstem, including live fish, carcasses, and redds, observed during surveys in 2006-2007.**

Seven surveys were conducted on 2 kilometers in John West Fork (reaches 1-2) between 11 December 2006 and 12 February 2007 (Table 2). The mean interval between surveys was nine days. Seven day rainfall totals during Julian week ranged from a low of 0 during Julian weeks 53 and 5 and a high of 5.54 during Julian week 6. Average water clarity at the time of surveys ranged from 30cm to 100cm. The onset of rainfall and subsequent higher flows appeared to be related to live fish observations.

In addition to John West Fork, four other tributaries to the Olema mainstem were surveyed between December and February. The timing of tributary surveys generally followed the mainstem surveys and were dependent on flow. Sections of Quarry Gulch, Giacomini Gulch, Horse Camp Gulch, and Boundary Gulch were surveyed.

**Table 2. Seven day total rainfall per Julian week, average water clarity, and the number of coho redds, coho carcasses, and live coho observed in 2006-07 on the John West Fork.**

Julian Week	Survey Date	Survey Reaches	Calendar Day	7 Day Rainfall during Julian Week (in)	Average Survey Water Clarity (cm)	Coho Redds	Coho Carcass	Live Coho
49	09 Dec 06			1.86				
50	11 Dec 06	1-2	345	2.65	80	2	0	4
(50)	14 Dec 06	1-2	348	(2.65)	60	6	1	10
51	19 Dec 06	1-2	353	0.84	100	10	1	7
52	29 Dec 06	1-2	363	2.28	70	10	1	17
53				0				
1				0.67				
2	08 Jan 07	1-2	8	0.02	100	1	2	0
3				0.03				
4				0.37				
5				0				
6	05 Feb 07	1-2	36	5.54	100	0	0	0
7	12 Feb 07	1-2	43	0.68	30	0	0	0
8				2.59				

Reach 1: Confluence with Olema Creek to HWY 1 culvert (0.2 km).

Reach 2: Hwy 1 culvert to monument tag OL-12-20 (1.8 km).

Reach 3: North Fork of John West Fork (0.4 km).

## **Live Fish, Carcass, and Redd Observations**

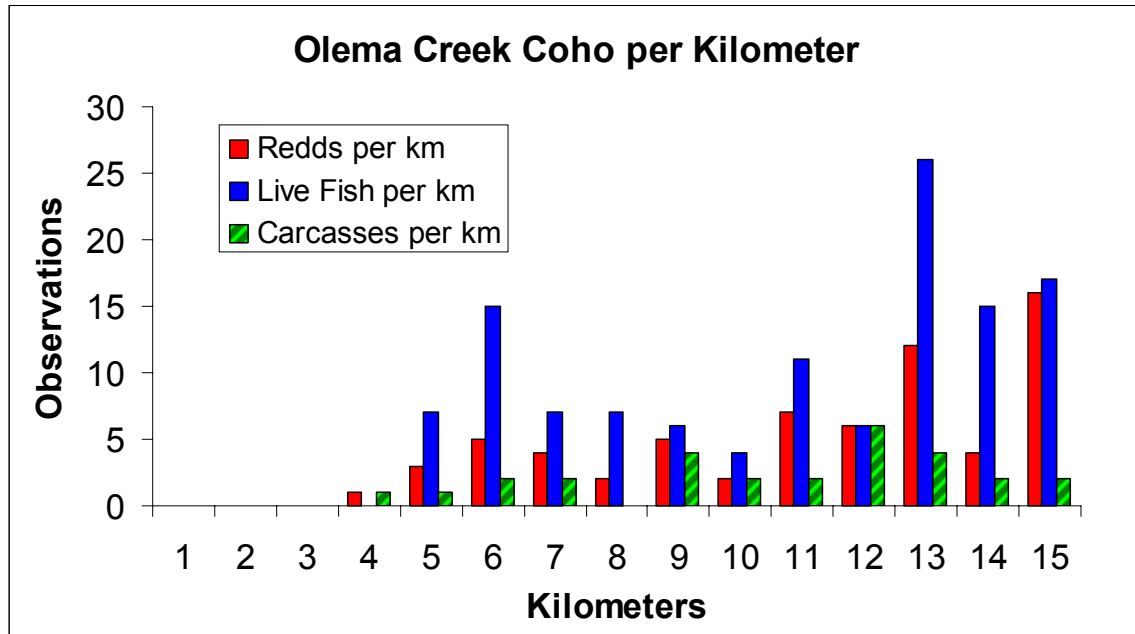
### ***Live Fish***

**Coho:** Spawner surveys of the Olema Creek mainstem were performed between November 21, 2006 and February 16, 2007. While live fish observations do not represent the total number of spawning adults, a total of 121 live adult coho were observed between November and February (Table 3). In the Olema mainstem, two peak spawning activities were observed on December 18 with 58 live coho and on January 10 with 17 live coho observed.

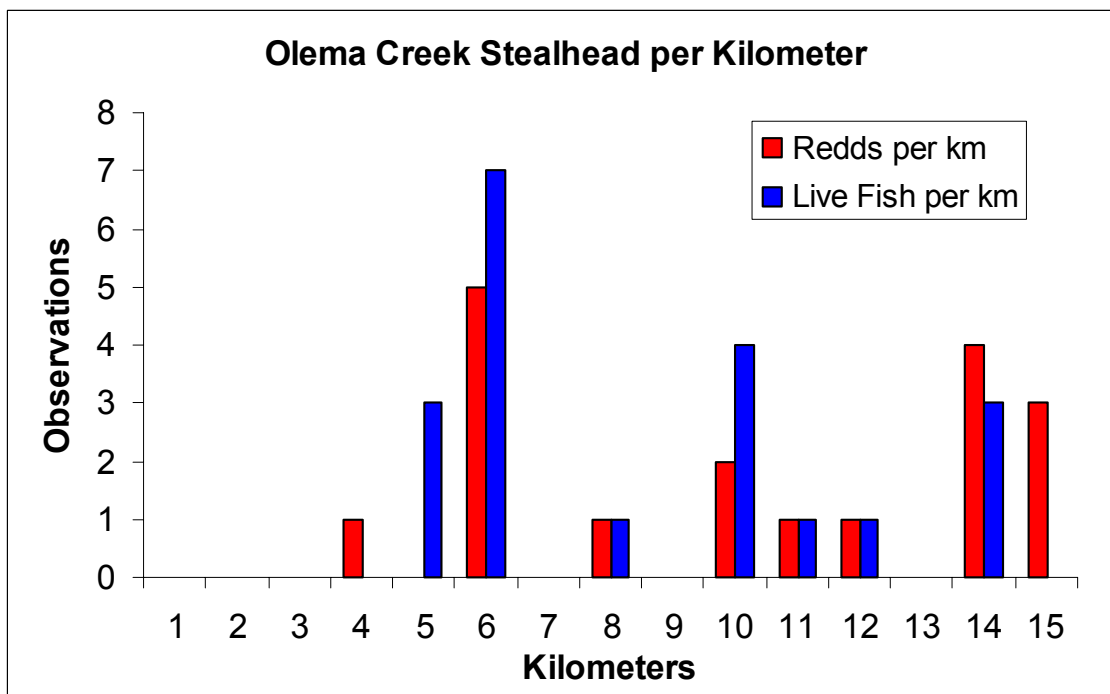
**Table 3. Olema Creek Mainstem 2006-2007 Spawner Survey**

Survey Date	Reach	# of Coho Redds		# of Adult Coho						Total Adults
				# of Live Adult Coho			# of Coho Carcasses			
		Definite	Possible	Male	Female	Unknown	Male	Female	Unknown	
11/21/06	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0
	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0
	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0
	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0
	Totals	0	0	0	0	0	0	0	0	0
12/18/06	2	3	0	7	7	0	0	0	0	14
	3	6	0	3	8	1	3	0	0	15
	4	0	0	0	0	0	0	0	0	0
	5	12	0	3	10	0	0	1	0	14
	6	13	1	8	11	0	1	0	0	20
	Totals	34	1	21	36	1	4	1	0	63
12/31/06	2	1	0	3	2	0	0	4	0	9
	3	3	0	1	4	1	0	2	0	8
	4	2	0	0	3	1	0	1	2	7
	5	9	0	8	10	0	0	0	0	18
	6	5	0	6	4	0	1	2	0	13
	Totals	20	0	18	23	2	1	9	2	55
01/10/07	2	4	0	0	2	0	0	0	0	2
	3	0	0	0	0	0	0	1	0	1
	4	0	0	0	1	0	0	0	0	1
	5	4	0	6	7	0	2	2	0	17
	6	1	0	0	1	0	0	0	0	1
	Totals	9	0	6	11	0	2	3	0	22
01/24/07	2	0	0	0	1	0	0	0	0	1
	3	0	1	1	0	0	0	0	0	1
	4	3	1	0	0	0	0	0	0	0
	5	0	0	1	0	0	1	2	1	5
	6	0	0	0	0	0	0	0	0	0
	Totals	3	2	2	1	0	1	2	1	7
02/16/07	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	1	0	1
	6	0	0	0	0	0	0	0	0	0
	Totals	0	0	0	0	0	0	1	0	1
Yearly Total Redds		66	3							

The total density of spawners during the first peak of the run was 5 fish/km. Most live fish (62% of the total count) were observed in survey reaches five and six (Figure 7). The sex ratio from live fish observations on the mainstem was 36% male, 59% female, 3% jacks and 2% unknown.



**Figure 7. Live coho fish, carcass, and redd observations by kilometer during spawner year 2006-07 on the Olema Creek mainstem.**



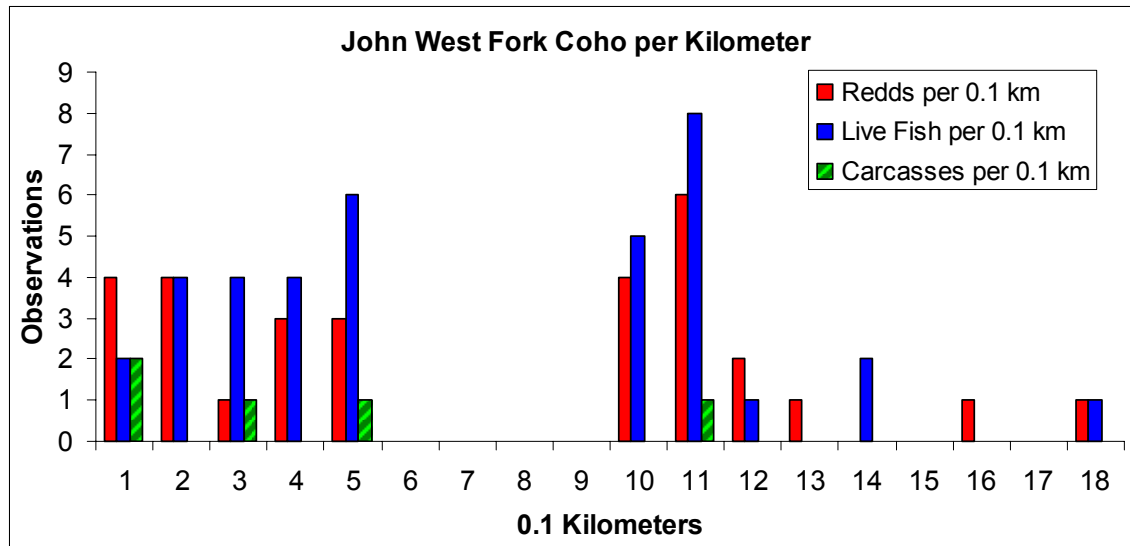
**Figure 8. Live steelhead fish and redd observations by kilometer during spawner year 2006-07 on the Olema Creek mainstem.**

John West Fork Creek, a tributary to Olema Creek, was first surveyed on December 11. A total of 38 live adults were documented on John West Fork, between December and February. Two peaks were observed on John West Fork with the first peak of 10 coho

observed on December 14 and the second peak of 17 fish occurring on December 29. A total of 24% of coho observed on John West Fork were counted within reach 1, the 200m section of stream below the State Route 1 culvert (Figure 9).

**Table 4. John West Fork 2006-2007 Spawner Survey**

Survey Date	Reach	# of Coho Redds		# of Adult Coho						Total Adults
				# of Live Adult Coho			# of Coho Carcasses			
		Definite	Possible	Male	Female	Unknown	Male	Female	Unknown	
12/11/06	1	0	0	0	0	0	0	0	0	0
	2	2	0	1	3	0	0	0	0	4
	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Totals	2	0	1	3	0	0	0	0	4
12/14/06	1	1	0	1	1	0	0	0	0	2
	2	5	0	3	5	0	1	0	0	9
	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Totals	6	0	4	6	0	1	0	0	11
12/19/06	1	4	1	0	1	0	0	0	0	1
	2	6	0	1	5	0	0	1	0	7
	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Totals	10	1	1	6	0	0	1	0	8
12/29/06	1	2	0	1	2	0	0	0	0	3
	2	8	0	5	9	0	1	0	0	15
	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Totals	10	0	6	11	0	1	0	0	18
01/08/07	1	0	0	0	0	0	0	0	1	1
	2	1	0	0	0	0	0	0	1	1
	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Totals	1	0	0	0	0	0	0	2	2
02/05/07	1	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0
	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Totals	0	0	0	0	0	0	0	0	0
02/12/07	1	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0
	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Totals	0	0	0	0	0	0	0	0	0
Yearly Total Redds		29	1							



**Figure 9. Live fish, carcass, and redd observations by kilometer during spawner year 2006-07 on the Olema Creek mainstem.**

Four additional tributaries to the Olema mainstem (Quarry Gulch, Boundary Gulch, Horse Camp Creek, and Giacomini Creek) and were surveyed between December and January. Of the four tributaries, a total of three live coho spawners were observed in Giacomini Creek on December 14 (Table 5).

**Table 5. Giacomini Creek 2006-2007 Spawner Survey**

Survey Date	Reach	# of Coho Redds		# of Adult Coho						Total Adults
				# of Live Adult Coho			# of Coho Carcasses			
		Definite	Possible	Male	Female	Unknown	Male	Female	Unknown	
12/14/06	1	0	0	0	2	1	0	0	0	3
12/29/06	1	0	0	0	0	0	0	0	0	0
Yearly Redd Totals		0	0							

Reach 1: Confluence with Olema Creek to ~ 300m upstream

**Steelhead:** Although adult steelhead were not a focus of this study, observations of steelhead were recorded in the same fashion as live adult coho. Actual live adult steelhead counts are assumed to be much higher than the observed counts. The peak steelhead count on Olema Creek was observed on February 16, 2007 with a count of 18 live adult steelhead. 50% of the total live adult steelhead counts were observed in survey reach two (Figure 8). Steelhead were observed on spawner surveys from December 31 to February 16 representing the highest total count of steelhead for all monitored years in Olema Creek. In addition, live adult steelhead were observed incidentally into late May on the mainstem of Olema Creek while operating a downstream migrant trap. No adult steelhead were observed during surveys performed on John West Fork Creek.



## **Carcasses**

**Coho:** A total of 27 carcasses were found on the mainstem of Olema Creek during the 2006-07 season (Table 3). Two marked carcasses were recaptured during subsequent surveys. Most carcasses were recovered during the December 31 surveys; thirteen days after the first peak number of live fish was observed (Figure 1). Most carcasses were found in survey reach 5 (Figure 7). The carcass sex ratio was 22% male, 60% female and 11% unknown. Based on the distribution of fish sizes, it appeared that jacks (precocious two-year old males) composed 7% of the recovered coho. Scales were collected from all individuals and we plan to use them to differentiate between two and three year old males. The mean fork length of male (excluding jacks) and female carcasses was 69cm and 65cm respectively. The results of previous spawner surveys in the Olema Creek watershed suggested that jacks were typically less than 50cm fork length. The mean length of males less than 50 cm fork length during the 2006-07 surveys was 39cm.

Of the five tributaries surveyed during the 2006-07 season, a total of 5 carcasses were found on John West Fork (Table 4). No marked carcasses were recovered. All of the carcasses were discovered between December 14 and January 8. The John West Fork carcass sex ratio was 40% male, 20% female, and 40% unknown.

**Steelhead:** Only one steelhead carcasses was recovered while performing spawner surveys on Olema Creek. It was recovered on January 16 and identified as a jack male with a fork length of 35cm. No steelhead carcasses were observed while surveying Olema Creek tributaries.

## **Redds**

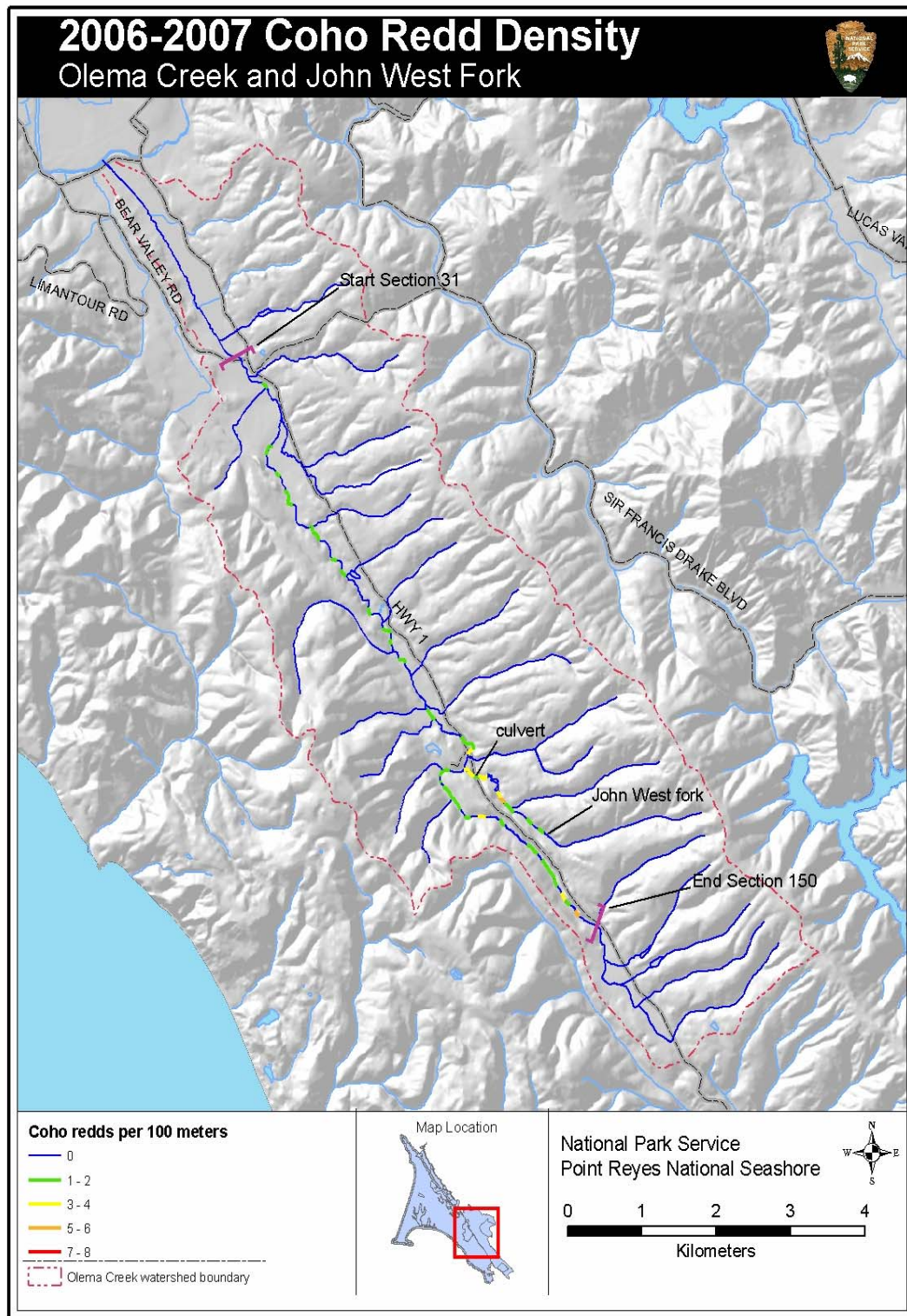
Redds are the best means of spatially representing use densities within the watershed. Within Olema Creek, monitoring efforts have allowed spatial representations of redd density per 100 meter monument tag since 1997-98 (Appendix A). Accumulation of this data show high use areas for spawning within the Olema and John West Fork watersheds.

**Coho:** A total of 66 confirmed redds were observed in the mainstem of Olema Creek during the 2006-07 season (Table 3). Redd construction was concentrated in survey reaches 5 and 6 where 67% of the redds were observed. Most mainstem redds were constructed between the December 18 and December 31 surveys. The total density of redds in the 11.6 km mainstem survey section was 5.7 redds/km. The mean surface area of all coho redds was 5.4m<sup>2</sup>. Observers made comments about features of the streambed that could not be positively identified as coho redds but were marked as possible redds instead. A total of 3 questionable redds were found. The mean surface area of the 3 questionable coho redds was 2.5m<sup>2</sup>.

A total of 29 definite coho redds were observed in John West Fork during the 2006-07 spawner season (Table 4). Redd construction was concentrated in survey reach 2 in John West Fork representing 76%. Coho redds were constructed between December 11 and January 8. The density of redds in the 2.0 km of streambed surveyed in John West Fork was 14.5 redds/km. Observers made comments of the streambed that could not be positively identified as coho redds but were marked as possible redds instead. Only one

questionable redd was observed. Figure 3.4 shows a map representing coho spawning density for the 2006-07 season.

**Steelhead:** A total of 17 definite steelhead redds and one potential redd were observed on Olema Creek between January 10 and February 16. Steelhead redd observations were concentrated in reaches 2 and 6 of Olema Creek representing 66% of confirmed steelhead redds. The density of redds in the 11.6km mainstem section surveyed was 1.5 redds/km. The mean surface area of the steelhead redds was 2.2m<sup>2</sup>. There were no steelhead redds identified in John West Fork during the 2006-07 spawner surveys due to low water levels.



**Figure 10. Coho redd density per 100 m within Olema Creek and John West Fork.**

## Escapement Estimates

### Area Under the Curve

Area Under the Curve (AUC) estimates were generated for live fish on Olema Creek mainstem and John West Fork during 2006-07 spawner surveys. When possible residence time (RT) was estimated based on observations of female coho holding on redds with the RT period equaling the previous storm event at time of entrance to the last observation of an individual female coho holding on a redd location. Observations of individual female coho salmon at the same redd location from one survey week to the next were considered to be the same fish. Observer efficiency was also estimated when possible based on average water clarity over the duration of the spawner season for each creek. When RT and OE values could not be determined AUC estimates were calculated based on values from published coho spawner studies. Eight studies were reviewed and had RT values ranging from eight to seventeen days. The most frequently reported values were eleven and thirteen days. Two of the eight studies reported OE values between 69 and 76 percent (Solazzi et al. 1984, Johnston et al. 1987). To consider a wider range of observer efficiencies, AUC estimates were calculated for OE values between 50 and 100 percent.

Population estimates in the Olema Creek section ranged from 80 to 170 coho at 100% OE and 160 to 341 fish at 50% OE (Table 6). Estimates from the most commonly reported OE (70-80%) and RT (11-13 days) values ranged from 131 to 177 fish in Olema Creek. Based on our survey OE and estimated RT, AUC estimates for coho salmon in Olema Creek range from 114 to 150.

Population estimates in the John West Fork survey section ranged from 16 to 34 coho at 100% OE and 32 to 68 fish at 50% OE (Table 7). Based on our survey OE and estimated RT, AUC estimates for coho salmon in John West Fork ranged from 32 to 45.

**Table 6. Area Under the Curve (AUC) population estimates for coho salmon adults in reaches 2-6 of Olema Creek during 2006-07.**

Residence Time (days)	Observer Efficiency					
	100%	90%	80% <sup>f</sup>	70% <sup>c</sup>	60%	50%
8 <sup>a</sup>	170	189	213	243	284	341
9 <sup>b</sup>	151	168	189	216	252	303
10 <sup>c</sup>	136	151	170	195	227	273
11 <sup>d,e,f</sup>	124	138	155	177	207	248
12	114	126	142	162	189	227
13 <sup>a,e,f,g</sup>	105	116	131	150	175	210
14 <sup>g</sup>	97	108	122	139	162	195
15 <sup>a</sup>	91	101	114	130	151	182
16	85	95	106	122	142	170

17 <sup>a</sup>	80	89	100	115	134	160
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a/ Irvine et al. (1992)  
 b/ van der Berghe and Gross (1986)  
 c/ Flint (1984)  
 d/ Beidler and Nickelson (1980)  
 e/ Johnston et al. (1987): 69% observer efficiency  
 f/ Crone and Bond (1976)  
 g/ Koski (1966)  
 h/ Solazzi et al. (1984): 76% observer efficiency

**Table 7. Area Under the Curve (AUC) population estimates for coho salmon adults in John West Fork during 2006-07.**

Residence Time (days)	Observer Efficiency					
	100%	90%	80% <sup>f</sup>	70% <sup>c</sup>	60%	50%
8 <sup>a</sup>	34	38	42	48	56	68
9 <sup>b</sup>	30	33	38	43	50	60
10 <sup>c</sup>	27	30	34	39	45	54
11 <sup>d,e,f</sup>	25	27	31	35	41	49
12	23	25	28	32	38	45
13 <sup>a,e,f,g</sup>	21	23	26	30	35	42
14 <sup>g</sup>	19	21	24	28	32	39
15 <sup>a</sup>	18	20	23	26	30	36
16	17	19	21	24	28	34
17 <sup>a</sup>	16	18	20	23	27	32

a/ Irvine et al. (1992)  
 b/ van der Berghe and Gross (1986)  
 c/ Flint (1984)  
 d/ Beidler and Nickelson (1980)  
 e/ Johnston et al. (1987): 69% observer efficiency  
 f/ Crone and Bond (1976)  
 g/ Koski (1966)  
 h/ Solazzi et al. (1984): 76% observer efficiency

### ***Peak Live plus Cumulative Dead***

Due to the three-month spawning period and the variability in residence time on the spawning grounds, the same live fish are often double counted during repeated surveys. An index derived from adding the peak number of live fish observed during a single survey to the number of carcasses recovered prior to that date provides a minimum spawner escapement estimate. The 2006-07 peak live plus cumulative dead (PLD) index was 80 on the Olema Creek mainstem and includes coho counts from December 18 and January 10. A PLD index of 28 coho was calculated for John West Fork and includes peak counts observed on December 14 and December 29.

## **2006-2007 Redwood Creek Adult Coho Escapement Results**

On November 12, 2006, a series of storm events increased stream flows to a level that breached the sand bar at Big Lagoon and allowed access for returning adult coho to the Redwood Creek watershed. Our first spawner survey was completed on Redwood Creek on November 20. A few adult coho were observed in Reach 1 during our first round of surveys representing the earliest return of coho since monitoring began in 1997. It was not until after the next winter storm on December 8 that we began to observe spawning activity.

Redwood Creek watershed spawner survey information includes data collected on 9.4 kilometers of the mainstem of Redwood Creek, reaches 1-3, and two major tributaries, Fern Creek and Kent Creek (see Figure 3). In the Redwood Creek mainstem, three peak spawning activities were observed on November 20 with 5 live coho, on January 16 with 15 live coho, and on January 9 with 8 live coho observed. A total of 21 definite coho redds were distributed throughout the mainstem of Redwood Creek.

### **Survey Timing and Environmental Conditions**

Nine surveys were conducted in Redwood Creek between 20 November 2006 and 15 February 2007 (Table 8). The mean interval between surveys was ten days. Seven day rainfall totals during Julian week ranged from a low of 0 during Julian weeks 53, 2, and 5 and a high of 3.03 during Julian week 50. Average water clarity at the time of surveys ranged from 48cm to 100cm. The onset of rainfall and subsequent higher flows appeared to be related to live fish observations (Figure 8).

**Table 8. Seven day total rainfall per Julian week, average water clarity, and the number of coho redds, coho carcasses, and live coho observed in 2006-07 on the Redwood Creek mainstem.**

Julian Week	Survey Date	Survey Reaches	Calendar Day	7 Day Rainfall during Julian Week (in)	Average Survey Water Clarity (cm)	Coho Redds	Coho Carcass	Live Coho
46	13 Nov 06			1.44				
47	20 Nov 06	1-3	324	0.1	100	0	0	5
48	29 Nov 06	1-3	333	0.13*	100	0	0	2
49	07 Dec 06	1-2	341	0.17*	100	0	0	1
50	16 Dec 06	1-5	350	3.03	48	7	0	17
51				0.01				
52	26 Dec 06	1-4		0.6*	96	2	2	8
(52)	30 Dec 06	1-3, 5	364	(0.6*)	65	3	1	5
53				0				
1				0				
2	09 Jan 07	1-3, 5	9	0	100	6	1	8
3				0.03				
4	23 Jan 07	1-3	23	0.2	100	3	2	0
5				0				
6				1.83*				
7	15 Feb 07	1-3, 5	46	0.3	50	0	0	0
8								

\*Rainfall total contains possible discrepancies between actual and reported due to loss of power to gage and/or possible debris within gage.

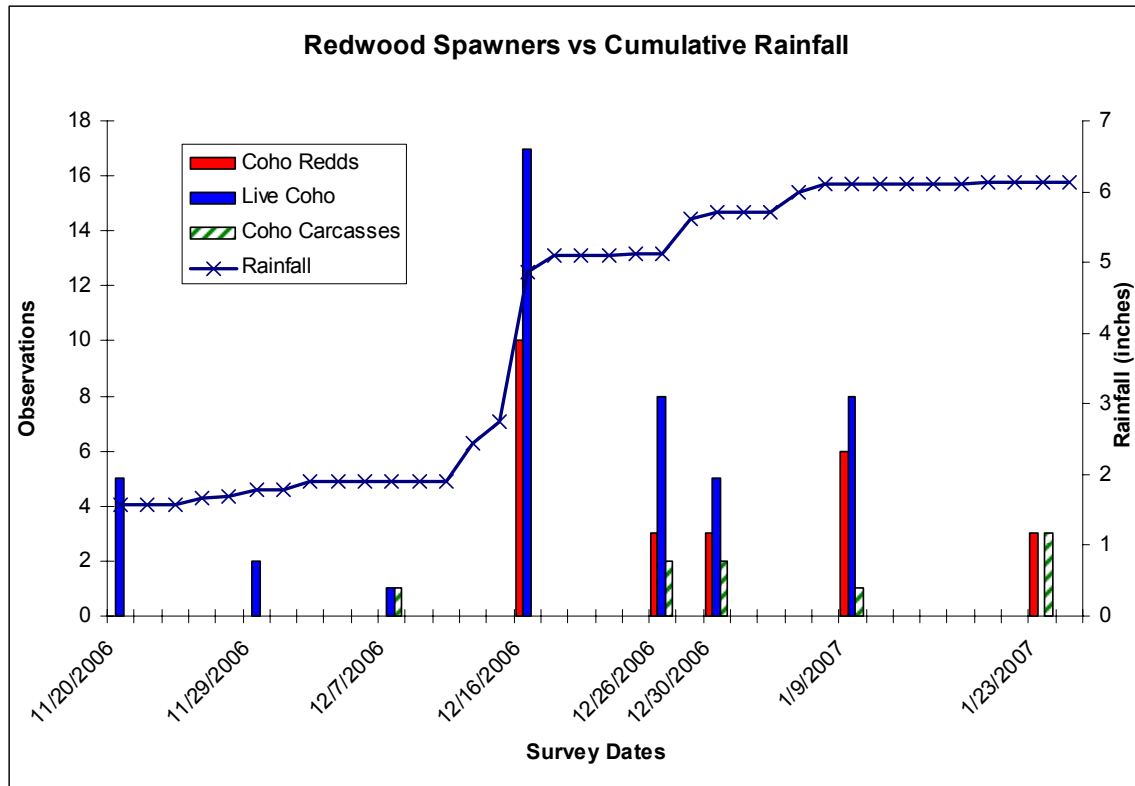
Reach 1: Pacific Way Bridge to the Kent Creek confluence in Mt. Tamalpais State Park (stream km 0.1 to 2.8)

Reach 2: Kent Creek confluence to Bridge 1 in Muir Woods (stream km 2.8 to 5.4)

Reach 3: Bridge 1 to 500m above Bridge 4 (stream km 5.4 to 7.4)

Reach 4: Kent Creek: confluence to water fall migration barrier (stream km 0 to 1)

Reach 5: Fern Creek: confluence to steep cascade (stream km 0 to 1)



**Figure 11. Representation of rainfall totals and adult escapement survey results on Olema Creek Mainstem, including live fish, carcasses, and redds, observed during surveys in 2006-2007.**

The Redwood Creek mainstem reaches 1 thru 3 were consistently sampled during each survey. Both Kent Creek and Fern Creek were surveyed when volunteer and staff turnout were high enough to cover both the mainstem and tributary reaches. Tributary reaches were surveyed on the same day as the mainstem reaches to eliminate the possibility of double counting.

## **Live Fish, Carcass, and Redd Observations**

### **Live Fish**

**Coho:** Spawner surveys of the Redwood Creek watershed were performed between November 20, 2006 and February 15, 2007. While live fish observations do not represent the total number of spawning adults, a total of 45 live coho adults were observed between November and February. In the Redwood Creek mainstem, three peak spawning activities were observed on November 11 with 5 live coho, on January 10 with 15 live coho, and on January 9 with 8 live coho observed. In addition, there was a total of 1 live adult coho located in Fern Creek on December 16 (Table 9).



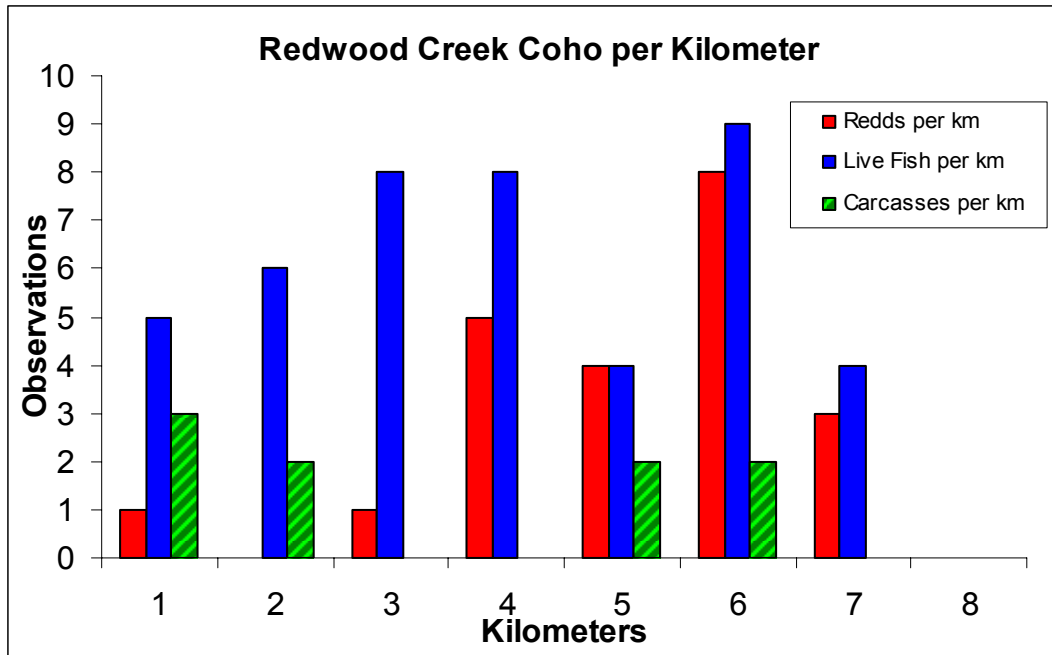
**Table 9. Redwood Creek Mainstem 2006-2007 Spawner Survey**

Survey Date	Reach	# of Coho Redds		# of Adult Coho						Total Adults
				# of Live Adult Coho			# of Coho Carcasses			
		Definite	Possible	Male	Female	Unknown	Male	Female	Unknown	
11/20/06	1	0	0	2	2	1	0	0	0	5
	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0
	Kent	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0
	Fern	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0
	Totals	0	0	2	2	1	0	0	0	5
11/29/06	1	0	0	1	0	1	0	0	0	2
	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0
	Kent	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0
	Fern	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0
	Totals	0	0	1	0	1	0	0	0	2
12/07/06	1	0	0	0	0	1	0	0	0	1
	2	0	0	0	0	0	0	0	0	0
	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0
	Kent	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0
	Fern	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0
	Totals	0	0	0	0	1	0	0	0	1
12/16/06	1	0	0	2	1	0	0	0	0	4
	2	4	0	2	5	1	0	0	0	8
	3	3	0	1	3	0	0	0	0	4
	Kent	0	0	0	0	0	0	0	0	0
	Fern	3	0	0	1	0	0	0	0	1
	Totals	10	0	5	10	1	0	0	0	17
12/26/06	1	0	0	1	1	0	1	1	0	4
	2	1	1	2	4	0	0	0	0	6
	3	1	0	0	0	0	0	0	0	0
	Kent	0	0	0	0	0	0	0	0	0
	Fern	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0
	Totals	2	1	3	5	0	1	1	0	10
12/30/06	1	0	0	0	0	0	0	1	0	1
	2	2	0	2	3	0	0	0	0	5
	3	1	0	0	0	0	0	0	0	0
	Kent	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0
	Fern	0	0	0	0	0	0	0	0	0
	Totals	3	0	2	3	0	0	1	0	6

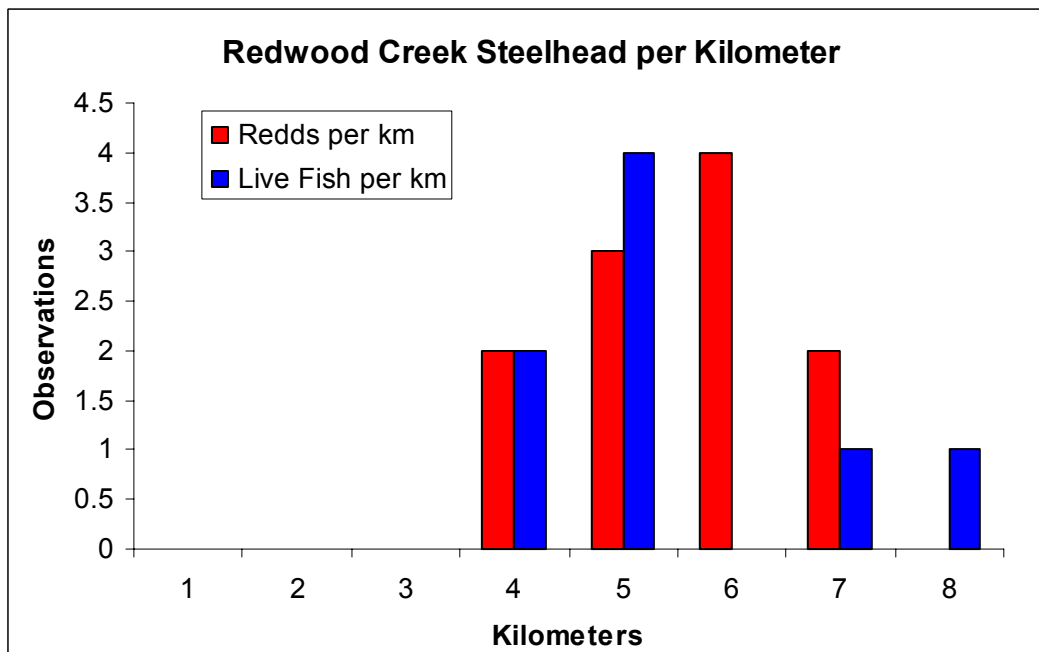
**Table 9. Redwood Creek Mainstem 2006-2007 Spawner Survey (continued)**

Survey Date	Reach	# of Coho Redds		# of Adult Coho						Total Adults
				# of Live Adult Coho			# of Coho Carcasses			
		Definite	Possible	Male	Female	Unknown	Male	Female	Unknown	
01/09/07	1	1	0	1	2	0	0	0	0	3
	2	2	0	0	4	0	0	1	0	5
	3	3	0	0	1	0	0	0	0	1
	Kent	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0
	Fern	0	0	0	0	0	0	0	0	0
	Totals	6	0	1	7	0	0	1	0	9
01/23/07	1	0	0	0	0	0	0	0	1	1
	2	3	0	0	0	0	0	1	0	1
	3	0	0	0	0	0	0	0	0	0
	Kent	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0
	Fern	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0
	Totals	3	0	0	0	0	0	1	1	2
02/15/07	1	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0
	Kent	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0
	Fern	0	0	0	0	0	0	0	0	0
	Totals	0	0	0	0	0	0	0	0	0
Yearly Total Redds		24	1							

The total density of spawners during the second peak of the run was 2 fish/km. Most live fish (52% of the total count) were observed in survey reach two (Figure 9). The sex ratio from live fish observations on the mainstem was 32% male, 59% female, and 9% unknown.



**Figure 12. Live coho fish, carcass, and redd observations by kilometer during spawner year 2006-07 on the Redwood Creek mainstem.**



**Figure 13. Live steelhead fish and redd observations by kilometer during spawner year 2006-07 on the Redwood Creek mainstem.**

**Steelhead:** Although adult steelhead were not a focus of this study, observations of steelhead were recorded in the same fashion as live adult coho. Actual live adult steelhead counts are assumed to be much higher than the observed counts. Steelhead were identified on spawner surveys conducted on January 9 and February 15. The peak

steelhead count in Redwood Creek was observed on February 15, 2007 with 8 live adult steelhead. Most live fish (75% of the total count) were observed in survey reach two (Figure 13). In addition, 6 live adult steelhead were located in the upper reaches of Fern Creek, a tributary to Redwood Creek, on February 15, 2007 where typically no adult salmonids are detected. Live adult steelhead have been observed into late March on the mainstem of Redwood Creek.

### **Carcasses**

**Coho:** A total of 6 carcasses were found on the mainstem of Redwood Creek during the 2006-07 season (Table 9). Two marked carcasses were recaptured during subsequent surveys. Carcasses were recovered between December 26 and January 23. The carcass sex ratio was 66% female and 17% unknown. Based on the distribution of fish sizes, it appeared that jacks (precocious two-year old males) composed 17% of the recovered coho. Scales were collected from all individuals and we plan to use them to differentiate between two and three year old males. The mean fork length of female carcasses was 66cm. The results of previous spawner surveys in the Redwood Creek watershed suggested that jacks were typically less than 50cm fork length. The mean length of males less than 50 cm fork length during the 2006-07 surveys was 44cm. No carcasses were located within Fern Creek or Kent Creek.

**Steelhead:** No steelhead carcasses were observed during surveys within the Redwood Creek watershed.

### **Redds**

**Coho:** A total of 21 confirmed redds were observed in the mainstem of Redwood Creek during the 2006-07 season (Table 9). Redd construction was concentrated in survey reach 2 where 57% of the redds were observed. Most mainstem redds were constructed between December 16 and January 23. The total density of redds in the 7.4 km mainstem survey section was 3 redds/km. The mean surface area of all coho redds was 5.6m<sup>2</sup>. Observers made comments about features of the streambed that could not be positively identified as coho redds but were marked as possible redds instead. One questionable redd was found.

A total of 3 definite coho redds were observed in Fern Creek during the 2006-07 spawner season (Table 9). Coho redds were discovered on December 16. The density of redds in the 1.0 km surveyed reaches of Fern Creek was 3 redds/km.

**Steelhead:** A total of 11 definite steelhead redds were observed in the mainstem of Redwood Creek between January 9 and February 15. Steelhead redd observations were primarily concentrated in reaches 2 representing 73% of confirmed steelhead redds. The total density of redds in the 7.4km mainstem section surveyed was 1.5 redds/km. The mean surface area of the steelhead redds was 2.12m<sup>2</sup>. There were 4 steelhead redds identified in Fern Creek on February 15.

## Escapement Estimates

### Area Under the Curve

Area Under the Curve (AUC) estimates were generated for live fish on Redwood Creek mainstem during 2006-07. When possible residence time (RT) was estimated based on observations of female coho holding on redds with the RT period equaling the previous storm event at time of entrance to the last observation of an individual female coho holding on a redd location. Observations of individual female coho salmon at the same redd location from one survey week to the next were considered to be the same fish. Observer efficiency was also estimated when possible based on average water clarity over the duration of the spawner season for each creek. When RT and OE values could not be determined AUC estimates were calculated based on values from published coho spawner studies. Eight studies were reviewed and had RT values ranging from eight to seventeen days. The most frequently reported values were eleven and thirteen days. Two of the eight studies reported OE values between 69 and 76 percent (Solazzi et al. 1984, Johnston et al. 1987). To consider a wider range of observer efficiencies, AUC estimates were calculated for OE values between 50 and 100 percent.

Population estimates in the Redwood Creek mainstem ranged from 24 to 50 coho at 100% OE and 46 to 98 fish at 50% OE (Table 10). Based on our survey OE and estimated RT, AUC estimates for coho salmon in Redwood Creek ranged from 39 to 51.

**Table 10. Area Under the Curve (AUC) population estimates for coho salmon adults during in Reaches 1-3 in the Redwood Creek mainstem during 2006-07.**

Residence Time (days)	Observer Efficiency					
	100%	90%	80% <sup>f</sup>	70% <sup>c</sup>	60%	50%
<b>8<sup>a</sup></b>	50	56	63	70	82	98
<b>9<sup>b</sup></b>	45	50	56	62	73	87
<b>10<sup>c</sup></b>	40	45	50	56	65	79
<b>11<sup>d,e,f</sup></b>	37	41	46	51	60	71
12	34	37	42	47	55	65
<b>13<sup>a,e,f,g</sup></b>	31	34	39	43	50	60
<b>14<sup>g</sup></b>	29	32	36	40	47	56
<b>15<sup>a</sup></b>	27	30	34	37	44	52
16	25	28	31	35	41	49
<b>17<sup>a</sup></b>	24	26	30	33	38	46

a/ Irvine et al. (1992)

b/ van der Berghe and Gross (1986)

c/ Flint (1984)

d/ Beidler and Nickelson (1980)

e/ Johnston et al. (1987): 69% observer efficiency

f/ Crone and Bond (1976)

g/ Koski (1966)

***Peak Live plus Cumulative Dead***

Due to the fact that coho return to spawn over a three-month period and residence time on the spawning grounds is variable, the same live fish are often double counted during repeated surveys. An index derived from adding the peak number of live fish observed during a single survey to the number of carcasses recovered prior to that date provides a minimum spawner estimate. The 2006-07 peak live plus cumulative dead (PLD) index was 28 on the Redwood Creek mainstem and includes coho counts from November 20, December 16, and January 9.

## 2006-2007 Pine Gulch Creek Adult Coho Escapement Results

Pine Gulch Creek spawner survey information includes data collected from 9.5km within two reaches (Figure 4). Four spawner surveys were conducted on Pine Gulch between November 30 and January 25 (Table 11).

### Survey Timing and Environmental Conditions

Four surveys were conducted in Pine Gulch between November 30, 2006 and January 25, 2007 (Table 11). The mean interval between surveys was fourteen days. Seven day rainfall totals during Julian week ranged from a low of 0 during Julian weeks 53 and 2 to a high of 5.9 during Julian week 50. Average water clarity at the time of surveys ranged from 70cm to 100cm.

**Table 11. Seven day total rainfall per Julian week, average water clarity, and the number of coho redds, coho carcasses, and live coho observed in 2006-07 on the mainstem of Pine Gulch Creek.**

Julian Week	Survey Date	Survey Reaches	Calendar Day	7 Day Rainfall during Julian Week* (in)	Average Survey Water Clarity (cm)	Coho Redds	Coho Carcass	Live Coho
46	13 Nov 06			3.77				
47				0.2				
48	30 Nov 06	1	334	1.42	70	0	0	0
49				1.09				
50	19 Dec 06	1-2	353	5.9	85	0	0	0
51				1.57				
52				1.43				
53	05 Jan 07	1-2	5	0	70	0	0	0
1				1.28				
2				0				
3				0.02				
4	25 Jan 07	1-2	25	0.5	100	0	0	0
5								

\*Rainfall totals contain possible discrepancies between actual and reported due to loss of power to gage and/or possible debris within gage.

Reach 1: Olema-Bolinas Road Bridge to Copper Mine Gulch Confluence (6.0 km)

Reach 2: Copper Mine Gulch Confluence to upstream of Teixeira to approximately monument marker 100 (3.5 km).

### Live Fish, Carcass, and Redd Observations

No live adult coho spawners, coho carcasses, or coho redds were observed during the 2006-07 spawner surveys on Pine Gulch Creek. No steelhead were discovered during the four spawner surveys but adult steelhead were observed on Pine Gulch into mid-April.

## 2006-2007 Cheda Creek Adult Coho Escapement Results

Cheda Creek is a small but important tributary of the Lagunitas Creek watershed and provides critical habitat for coho salmon (*O. kisutch*) and steelhead trout (*O. mykiss*). Cheda Creek spawner survey information includes data collected on 1.3 kilometers distributed between reaches 1-2 (see Figure 5). During spawner surveys conducted on Cheda Creek, one peak spawning activities was observed on December 29 with 5 live coho observed. A total of 7 definite coho redds were identified distributed throughout the Cheda Creek spawner survey reaches.

### Survey Timing and Environmental Conditions

Three surveys were conducted in Cheda Creek between 11 December 2006 and 29 December 2006 (Table 12). The mean interval between surveys was six days. Seven day rainfall totals during Julian week ranged from a low of 0.84 during Julian week 51 and a high of 2.86 during Julian week 50. Average water clarity at the time of surveys ranged from 45cm to 80cm.

**Table 12. Seven day total rainfall per Julian week, average water clarity, and the number of coho redds, coho carcasses, and live coho observed in 2006-07 on Cheda Creek.**

Julian Week	Survey Date	Survey Reaches	Calendar Day	7 Day Rainfall during Julian Week (in)	Average Survey Water Clarity (cm)	Coho Redds	Coho Carcass	Live Coho
49	9 Dec 06			0.96				
50	11 Dec 06	1-2	345	2.86	80	0	0	0
(50)	14 Dec 06	1-2	348	(2.86)	45	0	0	0
51				0.84				
52	29 Dec 06	1-2	363	2.28	60	7	1	5
53				0				

Reach 1: Confluence with Lagunitas Creek to 0.8 km upstream.

Reach 2: Upstream extent of the fish passage restoration site at 0.8 km upstream to 1.3 km upstream

### Live Fish, Carcass, and Redd Observations

#### Live Fish

Coho: Spawner surveys of Cheda Creek were performed between December 11, 2006 and December 29, 2006. While live fish observations do not represent the total number of spawning adults, a total of 5 live coho adults were observed during December. The sex ration from live fish observed on Cheda Creek was 20% male and 80% female.



**Steelhead:** No live adult steelhead or steelhead spawning activity was observed during the 2006-2007 spawner surveys.

**Table 13. Cheda Creek 2006-2007 Spawner Survey**

Survey Date	Reach	# of Coho Redds		# of Adult Coho						Total Adults
				# of Live Adult Coho			# of Coho Carcasses			
		Definite	Possible	Male	Female	Unknown	Male	Female	Unknown	
12/11/06	1	0	0	0	0	0	0	0	0	0
	2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0
	Totals	0	0	0	0	0	0	0	0	0
12/14/06	1	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0
	Totals	0	0	0	0	0	0	0	0	0
12/29/06	1	3	2	0	2	0	0	0	0	2
	2	4	0	1	2	0	1	0	0	4
	Totals	7	2	1	4	0	1	0	0	6
Yearly Redd Totals		7	2							

### **Carcasses**

**Coho:** One male coho carcass with a fork length of 70cm was found on Cheda Creek during the 2006-07 season (Table 13). A tissue sample was collected from this individual but the carcass was too degraded to collect a scale sample.

### **Redds**

**Coho:** A total of 7 confirmed redds were observed in Cheda Creek during the 2006-07 season (Table 13). Redd construction was distributed between reaches 1-2. All of the redds were observed during the survey on December 29. The total density of redds in the 1.3km survey section was 5.4 redds/km. The mean surface area of all coho redds was 3.0m<sup>2</sup>. Observers made comments about features of the streambed that could not be positively identified as coho redds but were marked as possible redds instead. A total of 2 questionable redds were found.

### **Escapement Estimates**

#### **Peak Live plus Cumulative Dead**

Due to the fact that coho return to spawn over a three-month period and residence time on the spawning grounds is variable, the same live fish are often double counted during repeated surveys. An index derived from adding the peak number of live fish observed during a single survey to the number of carcasses recovered prior to that date provides a minimum spawner estimate. The 2006-07 peak live plus cumulative dead (PLD) index was 6 on Cheda Creek and includes coho counts from December 29.

## **Watershed Summary of Adult Escapement Surveys**

### **Olema Creek**

Escapement monitoring information on Olema Creek shows that run timing is highly dependent on the rainfall-runoff condition within the watershed. Unlike Lagunitas Creek, Olema Creek is an unregulated stream. This makes conditions far more vulnerable to the variable environmental conditions that limit flows in the winter season. Adult coho salmon runs within the CCCESU are compressed into a very short window, with upstream migration coinciding with brief peak winter discharges, typically peaking in January (Weitkamp et.al. 1995). Freshwater residence time is short (typically less than 2 weeks), though the NPS program has documented some individuals spending up to 20 days in freshwater under ideal conditions.

### ***Survey Timing and Environmental Conditions***

Our monitoring efforts have shown some years where flows necessary to allow entry into the watershed did not occur until mid-January. In those years, fish were stacked in the estuary waiting for Olema Creek attraction flows. In other years, rains in November have resulted in flows that would allow coho access to the watershed. Even when the early entry opportunity has occurred in November, few coho have been observed. For the most part, peak of spawning within Olema Creek is between mid-December and mid-January. Typically the peak count will follow a large flow event, encouraging fish that were waiting at the mouth of the watershed to enter and spawn. Table 7.1 shows the approximate entry and spawning window monitored for coho salmon between spawner year (SY) 1997-98 and SY 2006-07.

Conditions where Olema Creek run timing was far different than that observed in Lagunitas Creek occurred in 1999-2000 and 2000-2001, where Olema entry flow was delayed by 2 months, and in 2002-2003 and 2003-2004, where Olema entry flows were delayed by one month. Surveys indicated that coho did indeed wait to enter the watershed, and that once in the stream, spawning occurred almost immediately. This behavior has raised an important question regarding how populations maintain themselves in a watershed with regulated and unregulated channels. The escapement and timing within the unregulated Olema Creek watershed may be affected negatively by outside influences.

Under State Water Resources Control Board Order 95-17, the Marin Municipal Water District is required to release winter attraction flows (>25 cfs for three days) through Lagunitas Creek prior to December 1 each year. Such releases in a low-flow year could attract fish that would otherwise move up Olema Creek. In addition, the estuary at the mouth of Olema Creek is highly constrained by levees associated with Sir Francis Drake

Blvd and the Giacomini Dairy. A project to remove several levees to restore the natural estuarine and flood plain processes is scheduled to begin in the fall of 2007. For fish that do remain near the mouth of Olema Creek for an attraction flow, the shallow, exposed pools may make adult salmon susceptible to both temperature effects and predation. Each of these factors may play into the escapement in years where natural rainfall runoff conditions are temporally distinct from the winter reservoir releases.

**Table 14. Coho salmon run timing, average total rainfall by month, and Olema Creek Peak Live plus Cumulative Dead (PLD), total carcasses and redds documented in the surveys for spawner years 1997-98 through 2006-07 within the Olema Creek mainstem.**

Spawner Year (SY)	Run Timing				Total Monthly Rainfall (in)				Olema Creek PLD			
	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Survey Area (km)	PLD Index	Total Carcass Counts	Total New Redds
1997-1998					10.32	3.47	16.49	24.68	13.4	88	39	126
1998-1999					7.48	2.21	7.66	15.61	11.6	42	13	42
1999-2000					5.2	0.99	7.15	12.77	7.2	9	9	10
2000-2001					1.54	1.31	6.45	8.07	11.6	103	65	86
2001-2002					9.81	15.03	5.08	3.55	11.6	90	28	58
2002-2003					3.3	17.33	3.75	2.34	11.6	20	17	5
2003-2004					2.71	12.14	5.13	7.68	11.6	138	34	88
2004-2005					0.65	10.13	4.85	5.33	11.6	184	63	92
2005-2006					3.27	19.9	7.94	4.76	11.6	12	11	2
2006-2007					5.54	7.64	1.09	9.93	11.6	80	27	66

### ***Watershed Escapement History and Estimates***

Escapement estimates for adults in Olema Creek have been made using both the Peak Live plus cumulative Dead (PLD) and Area Under the Curve (AUC) method. In years where persistent high flows resulted in a low number of surveys, both methods likely under-represented the true escapement number. The AUC method is dependent on two variables, observer efficiency (OE) and fish residence time (RT) in the freshwater following entry. In years where flows were high, both OE and RT were assumed to be lower than normal.

Annual escapement estimates for Olema Creek show a range of 9-184 using the PLD index. Estimates using the AUC method are much higher with estimates reaching beyond 300 adults in some years. The Olema Creek escapement estimates represent 20-40% of the total escapement estimated for the Lagunitas Creek watershed.

**PLD Index Results:** The PLD dataset for adult escapement within Olema Creek includes 13 years of survey information. It should be noted that prior to SY 1997-98, redds and carcasses were not consistently counted. Olema Creek mainstem (Table 15) and the John West Fork tributary (Table 16) are reported separately. PLD estimates have ranged from 9 to 184 for the mainstem and 8-86 for JWF. The John West Fork tributary has been the focus of extensive restoration and monitoring, and is often used as the proxy

of conditions in the mainstem. In the SY 1999-00 and SY 2002-03, PLD estimates and live fish observations on the two kilometer survey area of JWF exceeded those of the 13 kilometer mainstem. The results of SY 1999-00, SY 2002-03, and SY 2005-2006 are not considered representative of actual mainstem escapement due to poor survey conditions in the Olema mainstem during these years.

**Table 15. Coho Salmon Spawning Survey including Peak Live plus Cumulative Dead (PLD) Index, tally of total carcasses, and total redds for the Olema Creek mainstem.**

Year	Number of Surveys	Survey Area (km)	PLD Index	Total Carcasses	Total New Redds	Source
1994/95	3	13.4	53	1	9	Tomales Bay Association (TBA)
1995/96	2	13.4	106	37	N/A	Manning 1999
1996/97	2	15.6	174	16	N/A	Manning 1999
1997/98	8	13.4	88	39	126	Manning 1999
1998/99	6	11.6	42 <sup>a</sup>	13	42	NPS-PRNS
1999/00	2	7.2	9 <sup>b</sup>	9	10	NPS-PRNS
2000/01	4	11.6	103	65	86	NPS-PRNS
2001/02	4	11.6	90 <sup>c</sup>	28	58	NPS-PRNS
2002/03	4	11.6	20 <sup>b</sup>	17	5	NPS-PRNS
2003/04	6	11.6	138 <sup>d</sup>	34	88	NPS-PRNS
2004/05	6	11.6	184 <sup>d</sup>	63	92	NPS-PRNS
2005/06	3	11.6	12 <sup>b</sup>	11	2	NPS-PRNS
2006/07	6	11.6	80 <sup>d</sup>	27	66	NPS-PRNS

a/ Includes two peaks, 7 weeks apart.

b/ Surveys missed peak numbers.

c/ Includes two peaks, 4 weeks apart

d/ Includes two peaks, 3 weeks apart

N/A = not available.

**Table 16. Coho Salmon Spawning Survey including Peak Live plus Cumulative Dead (PLD) Index, tally of total carcasses, and total redds for the John West Fork of Olema Creek.**

Year	Number of Surveys	Survey Area (km)	PLD Index	Total Carcasses	Total New Redds	Source
1995/96	N/A	<1.0	8 <sup>a</sup>	N/A	N/A	NPS-PRNS
1996/97	N/A	N/A	N/A	N/A	N/A	NPS-PRNS
1997/98	5	1.3	12	0	7	NPS-PRNS
1998/99	2	1.2	9	0	1	NPS-PRNS
1999/00	3	1.1	18 <sup>b</sup>	0	7	NPS-PRNS
2000/01	4	1.9	58	30	48	NPS-PRNS
2001/02	6	1.9	20	5	31	NPS-PRNS
2002/03	7	1.3	27 <sup>c</sup>	0	12	NPS-PRNS
2003/04	6	2.4	41	7	21	NPS-PRNS
2004/05	7	2.4	86 <sup>d</sup>	12	45	NPS-PRNS
2005/06	7	2.4	8	0	4	NPS-PRNS
2006/07	7	2.4	28 <sup>e</sup>	5	29	NPS-PRNS

a/ Includes live fish only, no carcass data.

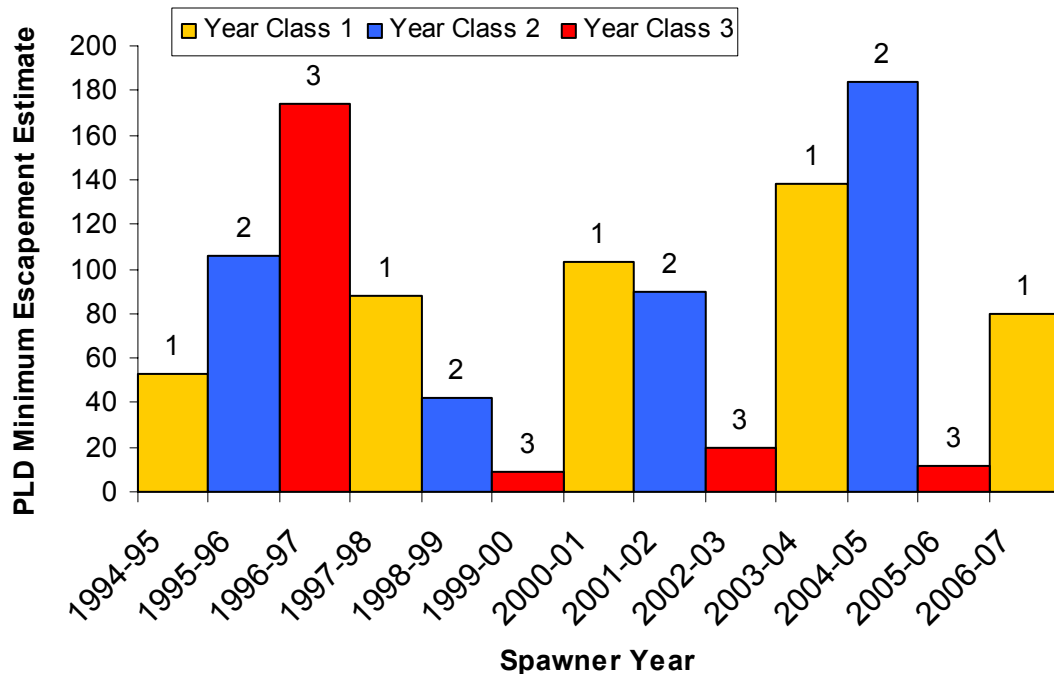
b/ Surveys missed peak numbers.

c/ Includes two peaks, 4 weeks apart

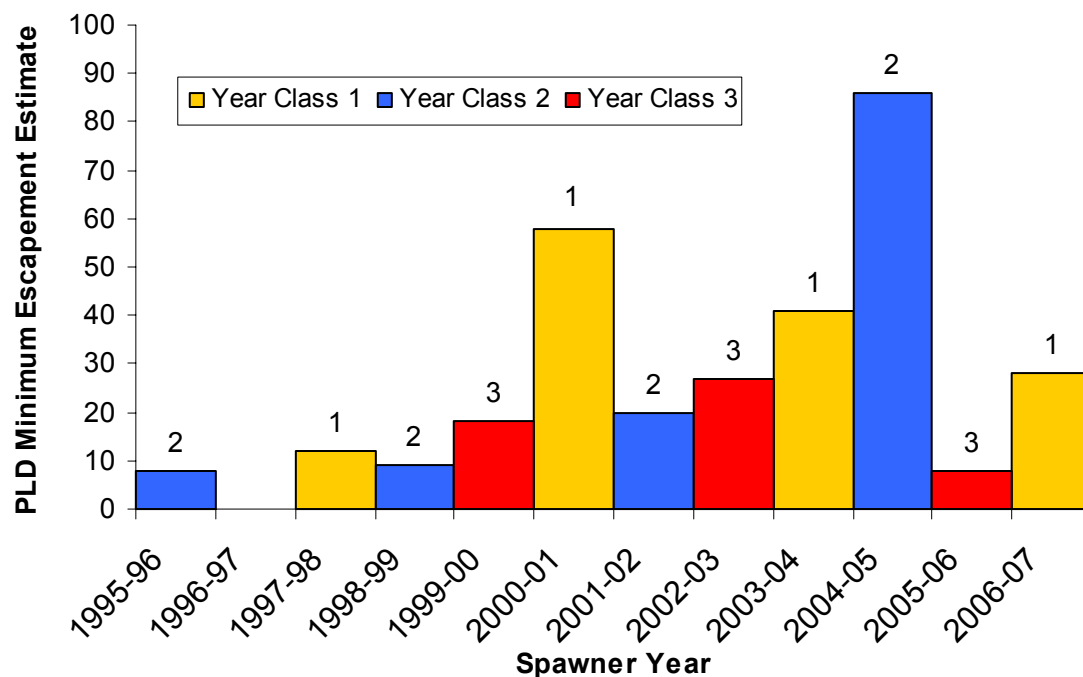
d/ Includes two peaks, 3 weeks apart

e/ Includes two peaks, 2 weeks apart

N/A = not available.



**Figure 14. Olema Creek Coho Salmon PLD Index Escapement results winter 1994-1995 through winter 2006-2007.**



**Figure 15. John West Fork Creek Coho Salmon PLD Index Escapement results winter 1995-1996 through winter 2006-2007.**

AUC Escapement Estimate: The PLD index is assumed to be a minimum count of fish within a watershed, as it is based on actual observations. The NPS has also used the AUC

method to estimate adult escapement within Olema Creek (Table 17) and the John West Fork tributary (Table 18). This method requires more consistent surveys and allows for an estimate of survey quality (observer efficiency) and the residence time of fish within the watershed. This method will tend to overestimate fish numbers where there are multiple peaks of fish or if there is a large interval between surveys. Only live fish are calculated using this technique.

**Table 17. Coho salmon spawning survey Area Under the Curve (AUC) estimates for Olema Creek, 1997-98 through 2006-07.**

Year	Number of Surveys	Date of Entry	Mean Survey interval (days)	Survey Reaches	Survey Area (km)	AUC Range 100% OE RT 8-17 days	AUC Range 50% OE RT 8-17 days	OLM Mainstem PLD
1997/98	7	15 Nov 97	7.9	2-4	4.5	56-118	112-236	88
1998/99	5	19 Nov 98	12.1	2-6	11.6	25-53	49-105	42
1999/00	2	18 Jan 00	N/A			N/A	N/A	9
2000/01	2	10 Jan 01	7.3	2-6	11.6	75-159	149-317	103
2001/02	3	24 Nov 01	12.3	2-6	11.6	105-224	210-447	90
2002/03	2	13 Dec 02	N/A			N/A	N/A	20
2003/04	4	14 Dec 03	11.8	2-6	11.6	138-293	275-585	138
2004/05	6	15 Dec 04	10.8	2-6	11.6	149-316	298-632	184
2005/06	3	01 Dec 05	16.6	2-6	11.6	N/A	N/A	12
2006/07	6	09 Dec 06	14.3	2-6	11.6	80-170	160-341	80

N/A – Survey data for mainstem not adequate to develop AUC estimate.

**Table 18. Coho salmon spawning survey Area Under the Curve (AUC) estimates for John West Fork, 1997-98 through 2006-07.**

Year	Number of Surveys	Date of Entry	Mean Survey interval (days)	Survey Reaches	Survey Area (km)	AUC Range 100% OE RT 8-17 days	AUC Range 50% OE RT 8-17 days	John West Fork PLD
1997/98	N/A	15 Nov 97	7.9					12
1998/99	N/A	19 Nov 98	12.1					9
1999/00	3	18 Jan 00	4.7	1-2	1.1	7-15	14-30	18
2000/01	4	10 Jan 01	9.4	1-2	1.9	42-90	85-180	58
2001/02	6	24 Nov 01	7.4	1-2	1.9	25-53	50-107	20
2002/03	6	13 Dec 02	6.9	1-2	1.3	14-30	28-61	27
2003/04	4	14 Dec 03	9.6	1-3	2.4	30-64	60-129	41
2004/05	7	10 Dec 04	8.8	1-2	1.8	60-127	120-255	86
2005/06	7	01 Dec 05	7.7	1-2	2.4	8-18	17-36	8
2006/07	7	09 Dec 06	9	1-2	2.4	16-34	32-68	28

N/A – Survey data for mainstem not adequate to develop AUC estimate.

### **Live Fish, Carcass, and Redd Observations**

Information on live fish, carcasses, and redds are collected during each field survey. Information on sex ratios for live fish and carcasses are reported in Table 19. While live fish lengths are estimated, carcasses are handled to definitively determine sex, spawn success, fork length (FL), and for collection of a genetic sample. The results of carcass measurements show that males are generally between 56-70 cm, with females averaging 50-67 cm and jacks averaging from 37-49 cm.

**Table 19. Sex ratios and size of live coho and carcasses within Olema Creek.**

		Live Coho		Carcasses			
		#	%	#	Mean FL	FL SD	
97-98	M	71	30%	16	47%	63.9 (n=15)	5.1
	F	95	40%	12	35%	59.1 (n=11)	3.1
	J	42	18%	5	15%	45.4 (n=5)	4.3
	Unk	29	12%	1	3%		
	All	237	100%	34	100%		
98-99	M	11	21%	4	31%	64.0 (n=2)	1.4
	F	25	47%	4	31%	61.0 (n=4)	3.4
	J	7	13%	3	23%	45.7 (n=3)	2.1
	Unk	10	19%	2	15%		
	All	53	100%	13	100%		
99-00	M	1	50%	2	22%	65 (n=1)	
	F	1	50%	6	67%	58.3 (n=6)	8.2
	J	0	0%	1	11%		
	Unk	0	0%	0	0%		
	All	2	100%	9	100%		
00-01	M	42	34%	22	34%	66.3 (n=22)	6.4
	F	61	50%	35	54%	65.4 (n=35)	4.7
	J	17	14%	8	12%	44.9 (n=8)	2.0
	Unk	3	2%	0	0%		
	All	123	100%	65	100%		
01-02	M	38	40%	8	30%	72.5 (n=6)	2.7
	F	46	48%	12	44%	66.7 (n=6)	6.3
	J	6	6%	1	4%	45 (n=1)	
	Unk	5	5%	6	22%		
	All	95	100%	27	100%		
02-03	M	0	0%	7	41%	68.8 (n=4)	6.3
	F	2	67%	0	0%		
	J	1	33%	2	12%	37.5 (n=2)	3.5
	Unk	0	0%	8	47%	57.5 (n=4)	14.4
	All	3	100%	17	100%		
03-04	M	37	26%	7	21%	74.3 (n=4)	1.5
	F	68	48%	11	32%	66.3 (n=10)	6.3
	J	31	22%	6	18%	45.2 (n=6)	2.0
	Unk	5	4%	10	29%	60.0 (n=4)	12.2
	All	141	100%	34	100%		
04-05	M	72	27%	24	38%	68.7 (n=14)	6.1
	F	114	42%	25	40%	65.7 (n=20)	3.3
	J	72	14%	1	1%	47.0 (n=1)	
	Unk	46	17%	13	21%	59.0 (n=4)	11.5
	All	269	100%	63	100%		
05-06	M	1	33%	3	27%	57 (n=1)	
	F	1	33%	4	36%	58.7 (n=3)	7.2
	J	1	33%	2	18%	40 (n=2)	7.1
	Unk	0		2	18%		
	All	3	99%	11	99%		
06-07	M	43	36%	6	22%	69 (n=6)	3.5
	F	71	59%	16	60%	65.3 (n=15)	3.8
	J	4	3%	2	7%	39 (n=2)	1.4
	Unk	3	2%	3	11%		
	All	121	100%	27	100%		

### ***Olema Creek Watershed Summary***

The emerging picture from 13 winters of coho spawner surveys on Olema Creek (Figure 14) reveals the presence of two strong year classes (year class 1 and 2) and one weak year class (year class 3). Previously, year class 3 was probably the strongest of the three, with a PLD index of 180 during the 1996-97 spawning run. However, the resulting cohort likely suffered high mortality during the last large-scale El Nino Southern Oscillation (ENSO) event in 1997-98. This event caused high flows during the winter of 1997-98 which may have resulted in low overwinter survival for the juvenile coho. Results of adult escapement and summer juvenile density monitoring indicate that the overwintering year class during the height of El Nino was the most heavily impacted and marks the shift of that cohort to the weakest year class. Although low spawner counts for the last three runs of this year class may be due in part to poor survey conditions, juvenile density observations support the notion that this became, and now remains the weakest year class.

On John West Fork Creek, 10 winters of coho spawning surveys (Figure 15) has revealed dramatic increase in coho spawners above the State Route 1 culvert (MP 22.67) since the completion of the culvert modification to improve fish passage. In spawner year 2006-07, there was an increase in redd construction but a decrease in the PLD index for year class 1 which may be due in part to poor survey conditions. In the 1999-2000 and 2002-2003 spawning years, JWF counts exceeded mainstem results, likely due in part to lower flows and better survey conditions on the tributary.

## **Redwood Creek**

### ***Survey Timing and Environmental Conditions***

Review of the thirteen years of escapement monitoring information on Redwood Creek indicates that run timing is highly dependent on the rainfall-runoff condition within the watershed (Table 20). Redwood Creek is an unregulated stream with variable environmental conditions that limit flows in the winter season. Adult coho salmon upstream migration coincides with brief peak winter discharges, typically peaking in January (Weitkamp et.al. 1995). Freshwater residence time is short (typically less than 2 weeks), though the NPS program has documented some individuals spending up to 20 days in the freshwater under ideal conditions.



**Table 20. Coho salmon run timing, average daily discharge by month, and Redwood Creek Peak Live plus Cumulative Dead (PLD), total carcasses and redds documented in the surveys for spawner years 1998-99 through 2006-07 within the Redwood Creek mainstem.**

Spawner Year (SY)	Run Timing				Total Monthly Rainfall (in)				Redwood Creek PLD			
	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Survey Area (km)	PLD Index	Total Carcasses	Total New Redds
1998-1999					3.28	1.49	5.27	8.47	9.4	39	10	58
1999-2000					2.72	0.59	5.95	0.00	8.4	10	1	7
2000-2001					0.00	0.00	4.39	6.07	9.4	49	13	35
2001-2002					0.00	0.00	0.83	3.56	9.4	105	63	47
2002-2003					2.18	13.04	1.23	1.83	9.4	24	3	7
2003-2004					2.62	3.45	7.21	6.38	9.4	67	25	43
2004-2005					0.8	7.59	3.66	3.09	9.4	171	76	93
2005-2006					2.19	12.57	0.00	3.48	9.4	27	5	12
2006-2007					2.58	4.27	0.63	3.63	9.4	28	6	21

### ***Watershed Escapement History and Estimates***

Escapement estimates for adults in Redwood Creek have been made using both the Peak Live plus cumulative Dead (PLD) and Area Under the Curve (AUC) method. In years where persistent high flows resulted in a low number of surveys, both methods likely under-represented the true escapement number. The AUC method is dependent on two variables, observer efficiency (OE) and fish residence time (RT) in the freshwater following entry. In years where flows were high, both OE and RT were assumed to be lower than normal.

**PLD Index Results:** The PLD dataset for adult escapement within Redwood Creek includes 13 years of survey information. It should be noted that prior to SY 1997-98, redds and carcasses were not consistently counted. PLD estimates have ranged from 10 to 171 (Table 21). The results of SY 1999-00, SY 2002-03, and SY 2005-2006 are not considered representative of actual mainstem escapement due to poor survey conditions. The 2004-05 spawner surveys had the highest PLD (171 adult coho) in the 16 year survey history. This is believed to be the strongest coho run since documentation of spawners were initiated in SY 1994-95. This is further supported by the total number of observed redds and carcasses (93 and 76 respectively). The 2006-07 spawner season was a disappointing one for Redwood Creek as returning spawners declined by over 50% for the year class.

**Table 21. Coho salmon spawning survey including Peak Live plus Cumulative Dead (PLD) Index, tally of total carcasses, and total redds for Redwood Creek.**

Year	Number of Surveys	Survey Area (km)	PLD Index	Total Carcasses	Total Redds	Source
1969	1	3.2	24	4	--	CDFG
1977-78	1	3.2	36	3	--	CDFG
1985-86	1	7.2	50	--	--	CDFG
1994-95	5	8.4 <sup>a</sup>	58	22	--	NPS Fong 1995
1995-96	5	8.4 <sup>a</sup>	27	18	--	NPS Fong 1996
1996-97	6	8.4 <sup>a</sup>	57	15	--	NPS Fong 1997
1997-98	7	9.4 <sup>b</sup>	65	30	80	NPS Manning 1999
1998-99	11	9.4 <sup>b</sup>	3 <sup>c</sup>	10	58	NPS CSRP
1999-00	6	8.4 <sup>a</sup>	10	1	7*	NPS CSRP
2000-01	5	9.4 <sup>a</sup>	49	13	35	NPS CSRP
2001-02	5	9.4 <sup>b</sup>	105 <sup>d</sup>	63	47	NPS CSRP
2002-03	5	9.4 <sup>b</sup>	24 <sup>e</sup>	3	7*	NPS
2003-04	6	9.4 <sup>b</sup>	67	25	43	NPS
2004-05	7	9.4 <sup>b</sup>	171 <sup>f</sup>	76	93	NPS
2005-06	5	9.4 <sup>b</sup>	27 <sup>e</sup>	5	12	NPS
2006-07	9	9.4 <sup>b</sup>	28 <sup>g</sup>	6	21	NPS

a – Includes the main stem of Redwood Creek and Fern Creek

b – Includes the main stem of Redwood Creek, Fern Creek, and Kent Creek

c – Includes two peaks, 7 weeks apart

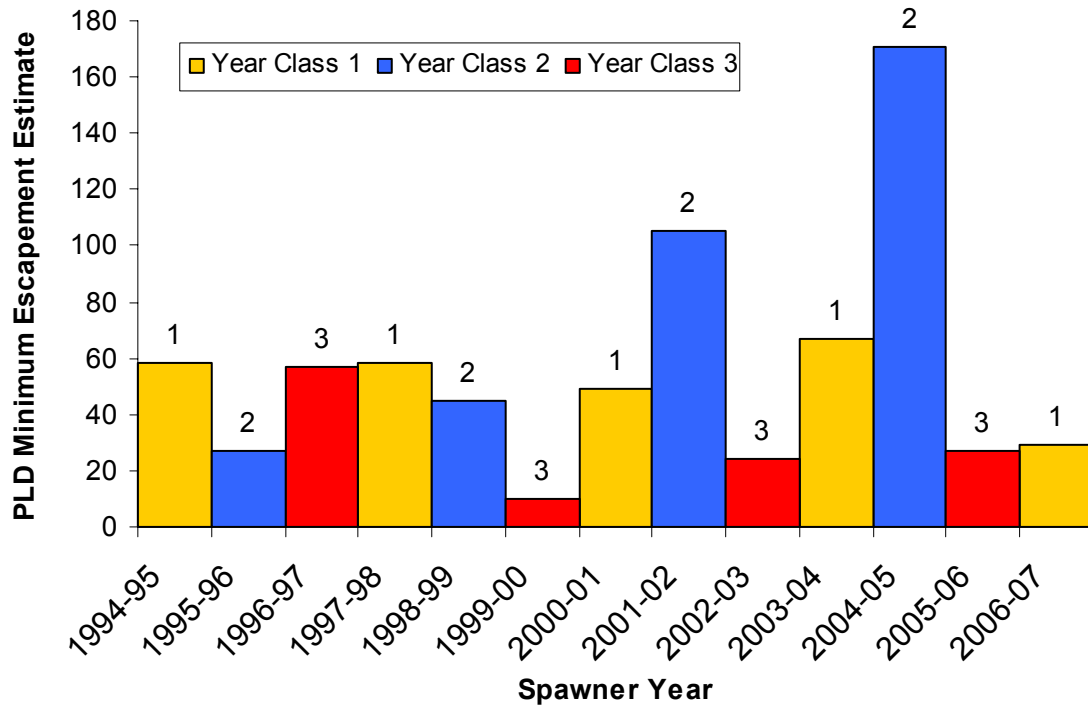
d – Includes two peaks, 22 days apart

e – Includes two peaks, 33 days apart

f – Includes two peaks, 25 days apart

g – Includes three peaks, 26 and 24 days apart

\* - Poor survey conditions resulted in low observer efficiency



**Figure 16. Redwood Creek Coho Salmon PLD Index Escapement results winter 1994-1995 through winter 2006-2007.**

**AUC Escapement Estimate:** The PLD index is assumed to be a minimum count of fish within a watershed, as it is based on actual observations. The NPS has also used the AUC method to estimate adult escapement within Redwood Creek (Table 22). This method requires more consistent surveys and allows for an estimate of survey quality (observer efficiency) and the residence time of fish within the watershed. This method will tend to overestimate fish numbers where there are multiple peaks of fish or if there is a large interval between surveys. Only live fish are calculated using this technique.

**Table 22. Coho salmon spawning survey Area Under the Curve (AUC) estimates for Redwood Creek, 1997-98 through 2006-07.**

Year	Number of Surveys	Date of Entry	Mean Survey interval (days)	Survey Length (km)	AUC Range 100% OE RT 8-17 days	AUC Range 50% OE RT 8-17 days	Redwood Creek PLD
1997/98	7	23 Nov 97	7.5	9.4	89-188	177-376	65
1998/99	11	29 Nov 98	8.6	9.4	39-83	78-167	39
1999/00	6	01 Jan 00	11.8	8.4	8-17	16-35	10
2000/01	5	15 Dec 00	13.0	9.4	74-157	148-314	49
2001/02	5	07 Dec 01	11.3	9.4	116-247	233-494	105
2002/03	5	10 Dec 02	14.0	9.4	22-46	43-92	24
2003/04	6	11 Dec 03	6.3	9.4	43-91	86-182	67
2004/05	7	06 Dec 04	8.3	9.4	169-359	338-718	171
2005/06	5	01 Dec 05	9.6	9.4	28-59	55-117	27
2006/07	9	13 Nov 06	10.4	9.4	24-50	46-98	29

***Live Fish, Carcass, and Redd Observations***

Information on live fish, carcasses, and redds are collected during each field survey. Sex ratios for live fish and carcasses are reported for each spawner year in Table 23. While live fish lengths are estimated (length to nearest 5cm), carcasses are handled to definitively determine sex, spawn success, fork length (FL), and to collect a genetics sample. The results of carcass measurements show that males are generally between 65-75 cm, with females averaging 57-67 cm and jacks (two year old males) averaging from 37-47 cm.

**Table 23. Sex ratios and size of live coho and carcasses within Redwood Creek.**

		Live Coho				Carcasses			
		#	%	Mean FL	FL SD	#	%	Mean FL	FL SD
97-98	M	12	26%	57.9(n=12)	5.42	6	25%	56.0(n=3)	6.56
	F	24	52%	56.9(n=24)	4.85	7	29%	54.8(n=6)	4.07
	J	4	9%	40.0(n=4)	0.00	4	17%	39.7(n=7)	1.25
	Unk	6	13%	53.3(n=6)	4.08	7	29%	60(n=2)	7.07
	All	46	100%			24	100%		
98-99	M	8	22%	61.3(n=8)	3.54	2	14%	62.0(n=2)	2.83
	F	16	44%	53.8(n=16)	3.87	6	43%	52.3(n=6)	2.58
	J	6	17%	36.7(n=6)	5.16	5	36%	42.2(n=5)	2.59
	Unk	6	17%	55.0(n=6)	4.47	1	7%		
	All	36	100%			14	100%		
99-00	M	3	33%	56.7(n=3)	11.55	0	0		
	F	4	44%	62.5(n=5)	11.9	1	100%	55.0(n=1)	
	J	0	0			0	0		
	Unk	2	22%	67.5(n=2)	3.54	0	0		
	All	9	100%			1	100%		
00-01	M	4	9%	60.0(n=4)	7.07	3	23%	62.5(n=2)	3.54
	F	14	30%	55.0(n=14)	4.39	6	46%	66.8(n=5)	2.94
	J	28	61%	39.1(n=28)	4.31	3	23%	42.7(n=3)	4.62
	Unk	0	0			1	8%	55.0(n=1)	
	All	46	100%			13	100%		
01-02	M	52	56%	59.2(n=51)	8.25	19	37%	70.1(n=19)	6.31
	F	31	33%	56.7(n=30)	6.34	20	38%	65.4(n=20)	5.28
	J	1	1%	45.0(n=1)		0	0		
	Unk	9	10%	57.1(n=7)	6.99	13	25%	64.9(n=7)	4.6
	All	93	100%			52	100%		
02-03	M	2	13%	65.0(n=2)	7.07	0	0		
	F	10	67%	53.6(n=7)	3.78	1	20%	50.0(n=1)	
	J	2	13%	42.5(n=2)	3.54	4	80%	36.5(n=4)	8.19
	Unk	1	7%	55.0(n=1)		0	0		
	All	15	100%			5	100%		
03-04	M	19	32%	62.0(n=19)	6.96	10	36%	63.8(n=8)	7.32
	F	26	43%	59.6(n=25)	4.55	13	46%	64.2(n=12)	5.39
	J	13	22%	35.4(n=13)	6.91	2	7%	40.5(n=2)	0.71
	Unk	1	2%	55.0(n=1)		3	11%	64.0(n=2)	1.41
	All	59	99%			28	100%		
04-05	M	69	40%	65.1(n=68)	5.50	18	26%	67.2(n=15)	4.68
	F	82	48%	60.1(n=78)	5.13	40	58%	63.3(n=40)	4.78
	J	9	5%	38.3(n=9)	2.50	1	1%	70.0(n=1)	
	Unk	11	6%	60.6(n=8)	6.23	10	14%	49.0(n=1)	
	All	171	100%			69	100%		
05-06	M	8	21%	69.4 (n= 8)	14.7	2	40%	57 (n=2)	1.4
	F	13	34%	60.4 (n=12)	5.8	3	60%	62 (n=3)	1.7
	J	12	32%	38.7 (n=12)	4.8	0			
	Unk	5	13%	57 (n=5)	2.7	0			
	All	38	100%			5	100%		
06-07	M	13	30%	63.4 (n=13)	4.7	0			
	F	26	59%	60.4 (n=26)	3.7	4	66%	66 (n=4)	5.8
	J	1	2%	45 (n=1)		1	17%	44 (n=1)	
	Unk	4	9%	57.5 (n=4)	2.89	1	17%	62 (n=1)	
	All	44	100%			6	100%		

### ***Redwood Creek Watershed Summary***

The emerging picture from 13 winters of coho spawner surveys on Redwood Creek (Figure 16) reveals the presence of one strong year class (year class 2), one weak year class (year class 3), and one moderate year class that may be in decline (year class 1). Previously, year class 3 was probably as strong as year class 1, with a PLD index of 57 during the 1996-97 spawning run. However, the resulting cohort probably suffered high mortality during the last large-scale El Nino Southern Oscillation (ENSO) event in 1997-98. This event caused high flows during the winter of 1997-98 which may have resulted in low overwinter survival for the juvenile coho. Results of adult escapement and summer juvenile density monitoring indicate that the overwintering year class during the height of El Nino was the most heavily impacted and marks the shift of that cohort to the weakest year class. Although low spawner counts for the last three runs of this year class may be due in part to poor survey conditions, juvenile density observations support the notion that this became, and now remains the weakest year class.

### **Pine Gulch Creek**

#### ***Watershed Escapement History and Estimates***

The dataset for the adult escapement within Pine Gulch Creek includes seven years of survey information following the discovery of one adult coho salmon during the SY 2000-01. Since this discovery, live adult coho and/or coho spawning activity have been sighted in the watershed during five out of the seven years. Summer juvenile coho surveys and spring downstream migrant traps have confirmed that a self propagating coho run does occur in Pine Gulch Creek.

**Table 24. Coho Salmon Spawning Survey including Peak Live plus Cumulative Dead (PLD) Index, tally of total carcasses, and total redds for the Pine Gulch Creek mainstem.**

Year	Year Class	Number of Surveys	Survey Area (km)	PLD Index	Total Carcasses	Total New Redds	Source
2000/01	1	3	7.0	1	0	0	NPS-PRNS
2001/02	2	2	9.0	2	0	2	NPS-PRNS
2002/03	3	2	8.0	2	2	1	NPS-PRNS
2003/04	1	6	9.0	0	0	0	NPS-PRNS
2004/05	2	3	10.0	3	0	3	NPS-PRNS
2005/06	3	4	9.5	0	0	1	NPS-PRNS
2006/07	1	4	9.5	0	0	0	NPS-PRNS

#### ***Pine Gulch Creek Watershed Summary***

Year class 2 appears to be strongest year class on Pine Gulch followed by year class 3 and 1. Although no returning adult or definite redds were observed during the 2003/04 spawner year, a basinwide survey conducted on Pine Gulch during the summer of 2004 revealed the presence of juvenile coho in the watershed (Ketcham et al. 2005b).

## Cheda Creek

### ***Watershed Escapement History and Estimates***

The dataset for adult escapement within Cheda Creek includes nine years of survey information and has documented the return of coho to the small tributary stream of Lagunitas Creek. Due to its small size and presence in the Lagunitas system, Cheda Creek spawner patterns are directly connected to those observed in the mainstem Lagunitas Creek. Our observations of Cheda Creek are intended to determine how a small downstream tributary is used by spawners in the context of the entire watershed.

The PLD index ranges from zero adults for the first three survey years to 17 adults observed in SY 2004-05. The first observed returning year class (SY 2001-02) appears to be coming back strong with both live adult observations and redd observations. The presence of spawning activity above the fish passage structure constructed in 2000 is a promising sign of recovery and documentation of the projects success.

**Table 25. Coho Salmon Spawning Survey including Peak Live plus Cumulative Dead (PLD) Index, tally of total carcasses, and total redds for Cheda Creek.**

Year	Number of Surveys	Survey Area (km)	PLD Index	Total Carcasses	Total New Redds	Source
1998/99	2	N/A	0	0	0	NPS-PRNS
1999/00	1	N/A	0	0	0	NPS-PRNS
2000/01	2	1.4	0	0	0	NPS-PRNS
2001/02	6	1.2	4	0	3	NPS-PRNS
2002/03	3	1.2	2	1	1	NPS-PRNS
2003/04	3	1.2	1	0	6	NPS-PRNS
2004/05	4	1.3	17 <sup>a</sup>	1	6	NPS-PRNS
2005/06	4	1.3	2	1	2	NPS-PRNS
2006/07	3	1.3	6	1	7	NPS-PRNS

a/ Includes two peaks, 3 weeks apart.

N/A-Survey Area Not Defined

### **Lagunitas Creek Watershed Summary for comparison (MMWD 2005)**

The PLD index data have not been consistently gathered for all creeks in the project area and can vary in quality depending on the number of surveys conducted and other factors. Data on the number of new redds provides a good overview of recent spawning activity in PRNS watersheds (Table 26). This data indicate the high annual variability in coho spawning activity and the relative importance of Olema Creek to spawning in the Lagunitas Creek drainage.

**Table 26. Total Coho Redds in Lagunitas Creek Watershed, 1995-2007 (MMWD & PRNS)**

Year	Lagunitas Creek mainstem	San Geronimo Creek (mainstem+tribs)	Devil's Gulch (+ Cheda)	Olema Creek (mainstem+tribs)	Total new redds	Olema Creek redd proportion
1995/96	70	6	10	N/A	86	N/A
1996/97	98	115	42	N/A	255	N/A
1997/98	80	107 + 14	46	126 + 7	380	35%
1998/99	92	46 + 14	31	42 + 1	226	19%
1999/00	139	58 + 3	3	10 + 7	220	8%
2000/01	119	56 + 18	11	86 + 48	338	40%
2001/02	79	102 + 43	59 + 3	58 + 31	375	24%
2002/03	71	39 + 22	24 + 2	5 + 12	175	10%
2003/04	124	139 + 66	48 + 6	88 + 21	492	22%
2004/05	120	140 + 18	112 + 6	92 + 45	633	22%
2005/06	53	48+56	33+2	2+4	198	3%
2006/07	128	117+38	55+7	66+29	440	22%

N/A = not available.

The contribution of the Lagunitas Creek mainstem to overall spawning activity in that drainage is indicated by data collected by MMWD since 1982 (Table 27) (MMWD 2003, MMWD 2005). Coho spawner counts and redd data show that much spawning activity takes place on Lagunitas Creek tributaries. Spawning on the mainstem takes place largely in Samuel P. Taylor State Park, upstream of PRNS-administered grazing lands.

**Table 27. Coho Salmon Spawning Survey Data for Lagunitas Creek Mainstem**

Year	Number of Surveys	PLD Index	Total Carcasses	Total New Redds	Source
1982/83	6	N/A	N/A	65	Bratovich & Kelly 1988
1983/84	6	N/A	N/A	26	Bratovich & Kelly 1988
1991/92	1	N/A	N/A	34	Wise 1992
1995/96	10	129 <sup>a</sup>	N/A	70	Trihey & Assoc. 1996
1996/97	8	170 <sup>a</sup>	23	98	Trihey & Assoc. 1997
1997/98	10	46	27	80	MMWD
1998/99	8	56 <sup>b</sup>	6	92	MMWD
1999/00	14	371 <sup>b</sup>	37	139	MMWD
2000/01	14	181 <sup>b</sup>	18	119	MMWD
2001/02	15	214 <sup>b</sup>	25	79	MMWD
2002/03	13	283 <sup>b</sup>	18	71	MMWD
2003/04	17	270 <sup>b</sup>	23	124	MMWD
2004/05	17	448 <sup>b</sup>	37	120	MMWD
2005/06	20	152	4	53	MMWD
2006/07	19	166	44	128	MMWD

a/ Peak live fish counts only, no cumulative dead.

b/ Corrected live fish observations reported by MMWD, may include repeat sightings of same fish

N/A= not available.

MMWD = Marin Municipal Water District data

The mouth of Lagunitas Creek and adjacent floodplain supports activities associated with the Waldo Giacomini dairy. This 563-acre property, once tidal wetlands, was diked and drained in the early 1940s to create pastures. For many years, a gravel dam was constructed annually just below the confluence of Lagunitas and Olema creeks for irrigation and stock watering. The dam created an abrupt transition from fresh to saline water for smolts and spawning adults, eliminating the transition zone found in an



unimpaired estuarine system. The transition zone allows smolting fish time to adjust to saline conditions and provides productive feeding zones where both freshwater and saltwater invertebrates are available.

Devil's Gulch has the longest period of spawner survey records for the Lagunitas Creek watershed (Table 28). CDFG biologist Eric Gerstung and warden Al Giddings noted live coho and steelhead observations from 1948 to 1977. Consultants for MMWD conducted surveys from 1982-84 and 1995-97. PRNS expanded the sampling area further upstream in 1996-97. Prior to 1982-83, no more than two surveys were conducted in a single season and carcasses and redd data were not consistently collected. During a single survey in 1948, 174 coho and steelhead were counted in a 2.6 km reach. Between 1957-58 and 1976-77, peak counts of live coho ranged between 70 and 130 fish. Coho numbers had dropped by the 1990s, with PLD index values between 1995-96 and 2002-03 ranging from 10 to 78 fish. Surveys in 2004-05 exceeded counts even back to 1948. The total PLD index of 207 spawning coho is calculated from two observed peaks 25 days apart. In addition, the 112 redds counted in the watershed far exceeds any counts in the last decade.

**Table 28. Coho Salmon Spawning Survey Data for Devil's Gulch**

Year	Number of Surveys	Survey Area (km)	PLD Index	Total Carcasses	Total New Redds	Source
1948	1	2.6	174 <sup>a</sup>	N/A	N/A	Gerstung & Giddings
1957/58	2	2.4	100 <sup>b</sup>	N/A	74	Gerstung & Giddings
1960/61	1	2.6	77 <sup>b</sup>	N/A	N/A	Gerstung & Giddings
1961/62	1	2.6	70 <sup>b</sup>	N/A	N/A	Gerstung & Giddings
1964/65	1	1.6	91	76	N/A	Gerstung & Giddings
1965/66	2	2.6	130 <sup>b</sup>	N/A	N/A	Gerstung & Giddings
1976/77	1	2.4	100	90	N/A	Gerstung & Giddings
1982/83	6	2.4	NA	N/A	23	Bratovich & Kelly 1988
1983/84	6	2.4	NA	N/A	11	Bratovich & Kelly 1988
1995/96	6	2.4	19 <sup>b</sup>	N/A	10	Trihey & Assoc. 1996
1996/97	3	3.2	47	20	42	Trihey & Assoc. 1997; PRNS
1997/98	8	3.2	27	9	46	PRNS
1998/99	6	3.2	26	6	31	PRNS
1999/00	2	3.2	10	1	3	PRNS
2000/01	4	3.2	14	2	11	MMWD
2001/02	11	3.2	46	12	59	MMWD
2002/03	5	3.6	87 <sup>c</sup>	1	24	MMWD
2003/04	10	3.6	76 <sup>d</sup>	12	48	MMWD
2004/05	14	3.6	207 <sup>e</sup>	32	112	MMWD
2005/06	9	3.6	64	7	33	MMWD
2006/07	10	3.6	73	3	55	MMWD

a/ Peak live fish count includes both coho and steelhead, does not include carcass data.

b/ Peak live fish counts without accumulated carcass data.

c/ two peaks, 27 days apart

d/ two peaks, 24 days apart

e/ two peaks, 25 days apart

N/A = not available.

MMWD = Marin Municipal Water District data; PRNS = Point Reyes National Seashore data

## Discussion and Conclusion

Coastal Marin County watersheds are some of the most intensely monitored watersheds for coho salmon within the Central California Coast ESU. In addition to our NPS/DFG funded monitoring efforts on Olema Creek, Redwood Creek, Pine Gulch Creek and Cheda Creek, extensive monitoring is conducted by Marin Municipal Water District (MMWD) on Lagunitas Creek, Devils Gulch, and mainstem of San Geronimo Creek, and by the Salmon Protection and Watershed Network (SPAWN) on tributaries of San Geronimo Creek. Through these combined monitoring efforts, we have documented significant information about coho salmon behavior, distribution, and use of these small coastal watersheds.

The intensity of our life-cycle monitoring programs allow for larger scale characterization of patterns observed in the area. Though a relatively small geographic area, the coastal Marin watersheds support a significant proportion of the CCCESU coho salmon, as well as two genetically distinct subpopulations. Genetic evaluations suggest that coho salmon occurring in Olema Creek and Cheda Creek constitute part of the Lagunitas/Olema genetic subgroup that would likely encompass the entire Tomales Bay watershed. Genetic evaluations also suggests that the Pine Gulch Creek population represents an expansion of the Redwood Creek coho population to a new watershed (Garza and Gilbert 2003).

Both the Olema Creek and Cheda Creek watersheds show the pattern of two stronger year classes SY 2006-07 (Year Class 1) and SY 2004-05 (Year Class 2), and one weak year class, SY 2005-06 (Year Class 3). In the Redwood Creek watershed data indicates the presence of only one strong year class SY 2004-05 (Year Class 2), one moderate year class that may be in decline, SY 2006-07 (Year Class 1), and one weak year class, SY 2005-06 (Year Class 3). In the Pine Gulch watershed adult coho numbers have been insufficient to distinguish a justifiable year class pattern from the available data. The last two years, SY 2006-07 and SY 2005-06, represent reduced escapement results from previous year classes for all monitored watersheds. We surmise that the strongest year class prior to the 1997-98 ENSO event, Year Class 3, was severely impacted as fish attempted to overwinter during the El Nino winter.

From our observations, the 2006-2007 coho salmon represented a moderate to strong cohort based on previous year class observations. January was a very dry month and had the direct effect of considerably reducing spawning activity. Not only did this reduced creek flows for spawning activity but also jeopardized redds that were constructed in the tributaries and in the mainstem of Olema and Redwood creeks.

The Olema Creek mainstem experienced a 25% decline in coho redds for the 2006-2007 year class compared to 2003-2004. John West Fork, a tributary to Olema Creek, showed a 28% increase in total redd production from the previous year class. Thus total Olema Creek watershed redd numbers, which takes into account John West Fork, declined by 13%. Redwood Creek mainstem had a 51% decline in total coho redd production from the previous year class. Of the four consecutively monitored year classes on Redwood

Creek, 2006-2007 had the lowest coho spawning activity. On Pine Gulch, no spawning activity was observed. Cheda Creek, a tributary to Lagunitas Creek, showed a slight increase in redd development along with an increase in returning adult coho spawners.

The patterns represented in our monitoring data suggest regional influences on the coho salmon escapement observed over the past decade. Overall coho escapement within Marin County watersheds has been trending upward since the 1997-98 ENSO event likely triggered by the Pacific Decadal Oscillation (PDO), shifting the dominant productivity from the Alaska Current to the California Current in the late 1990s. Since 1999, all three coho year classes in Olema Creek and Redwood Creek have shown a strong response to these changed ocean productivity patterns. This upward trend is most prominent in the documented return of coho salmon to the Pine Gulch Creek watershed in winter 2000-2001. Increases in adult escapement have translated into large shifts in juvenile coho density and smolt production at all monitoring locations. Continued monitoring efforts will allow for better characterization of year classes and annual productivity of coho salmon within coastal Marin County watersheds.

As a measure of the overall watershed escapement, redd information is reported as density per kilometer (Table 29). This measure will be used for comparative purposes with the juvenile and smolt densities observed within the monitored areas in each watershed. Redd density per kilometer is also the only parameter reliably measured in all of the watersheds and will thus be used for watershed comparisons. Redd densities appear to be highly variable from year to year in all of the unregulated streams surveyed in Marin County while redd densities within Lagunitas Creek, a regulated stream, appears to remain fairly constant. This further supports the relationship of winter flows to spawning success in the coastal streams of Marin County.

Our data indicates a strong correlation between adult spawner density and the summer juvenile density, suggesting that year class is the dominant factor associated with population observations in these watersheds. We have observed that high winter spawner numbers have been consistent with increased juvenile densities the following summer, with a peak following SY 2004-2005.

### **Adult Escapement Monitoring Recommendations**

Our program now includes 13 years of spawner survey information within the Marin County watersheds. Volunteer participation continues to be a critical component to the success of our adult escapement surveys. We plan to continue these efforts, making a point to increase frequency (see methods below) so that we can employ additional statistical evaluation to determine actual escapement.

### **Methods**

Adult spawner surveys have been conducted based on environmental conditions. Staff should work to increase survey frequency to improve our ability to conduct Area Under the Curve (AUC) estimates. The current surveys are adequate, and provide good AUC

estimates in some years. Increasing survey frequency may involve conducting more surveys under suboptimal conditions to estimate watershed escapement.

While fish are constantly moving and recounts would not readily improve results, redds are identified and measured as a means to indicate coho productivity within a watershed. Investigations by the CDFG in northern California indicate that measuring the surface area of redds can be a good measure of female effort and reproduction within a watershed (Gallagher and Gallagher 2005). Staff should follow up watershed scale surveys with redd based surveys to collect more detailed redd dimension information, as well as to confirm redd identification and/or locate missed redds. Increased redd information combined with a better understanding of female redd effort could be used as a measure to determine total egg distribution in any given year.

### ***Analysis***

Staff should continually update and maintain previous and current datasets. The analysis of spawner survey data should be reported annually in conjunction with the results of other coastal Marin County watersheds. Further analysis and standard protocols on redd documentation should be made on a regional level as this is the only comparable data set between surveys performed by other agencies in Marin County. Data should also be compared to monitoring being performed on other California coastal streams in order to determine an accurate level of ocean survivorship. As noted above, additional effort related to redd investigations will add a valuable component (egg and escapement estimates) to the data already collected through this program. As a measure of watershed success, egg to smolt survival should be analyzed. Increased analysis of these life stages would provide additional information of potential population bottlenecks.

**Table 29. Coho Spawner Survey Redd Density History for mainstem Lagunitas Creek, San Geronimo Creek, Devil's Gulch, Olema Creek, John West Fork, Redwood Creek, and John West Fork including total redds, survey length and redd density.**

Years	Lagunitas Creek			San Geronimo Creek			Devil's Gulch			Olema Creek			John West Fork			Redwood Creek			Pine Gulch		
	Total Redds	Survey Length	Redd Density	Total Redds	Survey Length	Redd Density	Total Redds	Survey Length	Redd Density	Total Redds	Survey Length	Redd Density	Total Redds	Survey Length	Redd Density	Total Redds	Survey Length	Redd Density	Total Redds	Survey Length	Redd Density
1997-1998	80	10.7	7.5	107	7.0	15.3	52	3.2	16.3	126	13.4	9.4	7	2.0	3.5	74	7.4	10.0	N/A	N/A	N/A
1998-1999	92	10.7	8.6	46	7.0	6.6	32	3.2	10	42	11.6	3.6	1	2.0	0.5	55	7.4	7.4	N/A	N/A	N/A
1999-2000	139	10.7	13.0	58	7.0	8.3	3	3.2	0.9	10	7.2	1.4	7	2.0	3.5	7	7.4	0.9	N/A	N/A	N/A
2000-2001	119	12.8	9.3	56	7.0	8.0	11	3.2	3.4	86	11.6	7.4	48	2.0	24	35	7.4	4.7	0	9.5	0
2001-2002	79	12.8	6.2	102	7.0	14.5	59	3.7	16.1	58	11.6	5.0	31	2.0	15.5	29	7.4	3.9	2	9.5	0.2
2002-2003	71	12.8	5.5	39	7.0	5.6	24	3.7	6.6	5	11.6	0.4	12	2.0	6	5	7.4	0.7	1	9.5	0.1
2003-2004	124	12.8	9.7	139	7.0	19.8	48	3.7	13.1	88	11.6	7.6	21	2.0	10.5	43	7.4	5.8	0	9.5	0
2004-2005	120	12.8	9.4	138	7.0	19.7	112	3.7	30.6	92	11.6	7.9	45	2.0	22.5	74	7.4	10.0	3	9.5	0.3
2005-2006	53	12.8	4.1	48	7.0	6.9	33	3.7	8.9	2	11.6	0.2	4	2.0	2	12	7.4	1.6	1	9.5	0.1
2006-2007	128	12.8	10	117	7.0	16.7	55	3.7	14.9	66	11.6	5.7	29	2.0	14.5	21	7.4	2.8	0	9.5	0

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NPS D-XXX, June 2007

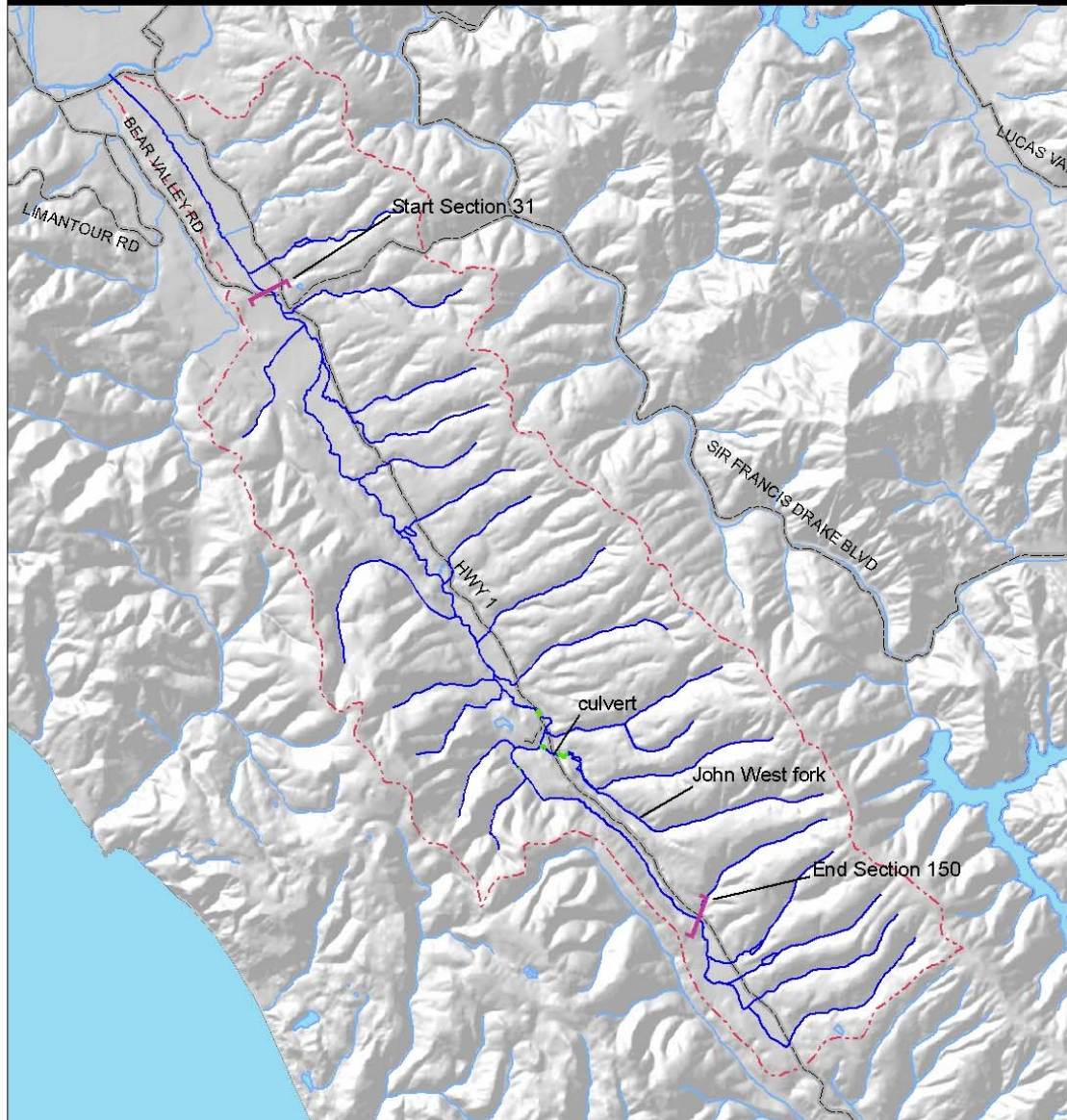
## **Appendix A**

### **Olema Creek Watershed Redd Distribution Maps 1997-98 to 2003-04**

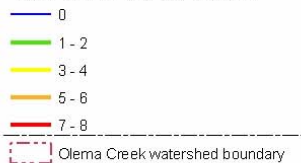
note: 2006-07 is Figure 3.4

# 2005-2006 Coho Redd Density

## Olema Creek and John West Fork



### Coho redds per 100 meters



### Map Location

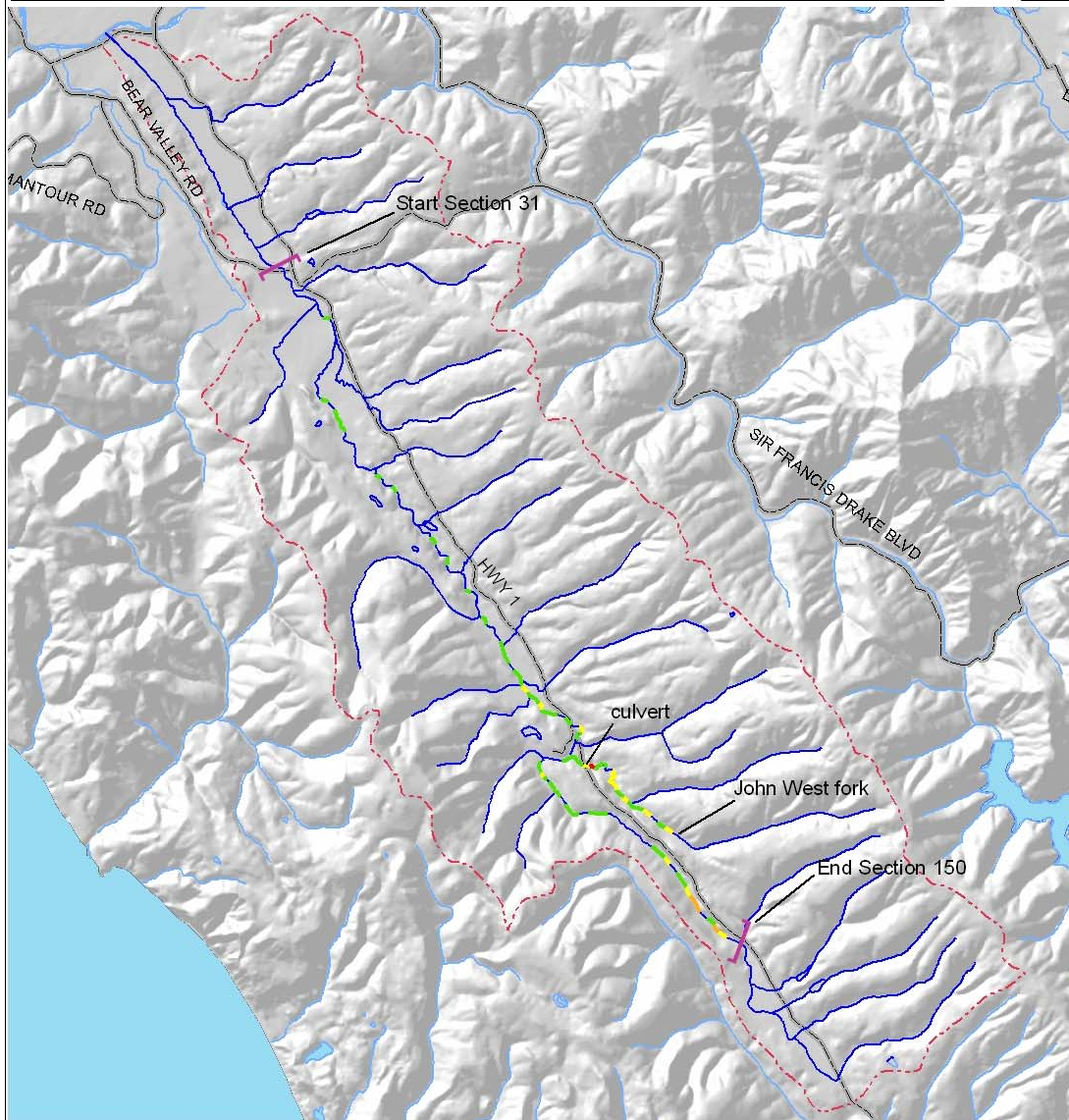


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Point Reyes National Seashore

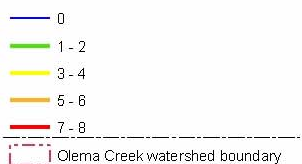


# 2004-2005 Coho Redd Density

## Olema Creek and John West Fork



### Coho redds per 100 meters



### Map Location



National Park Service  
Point Reyes National Seashore

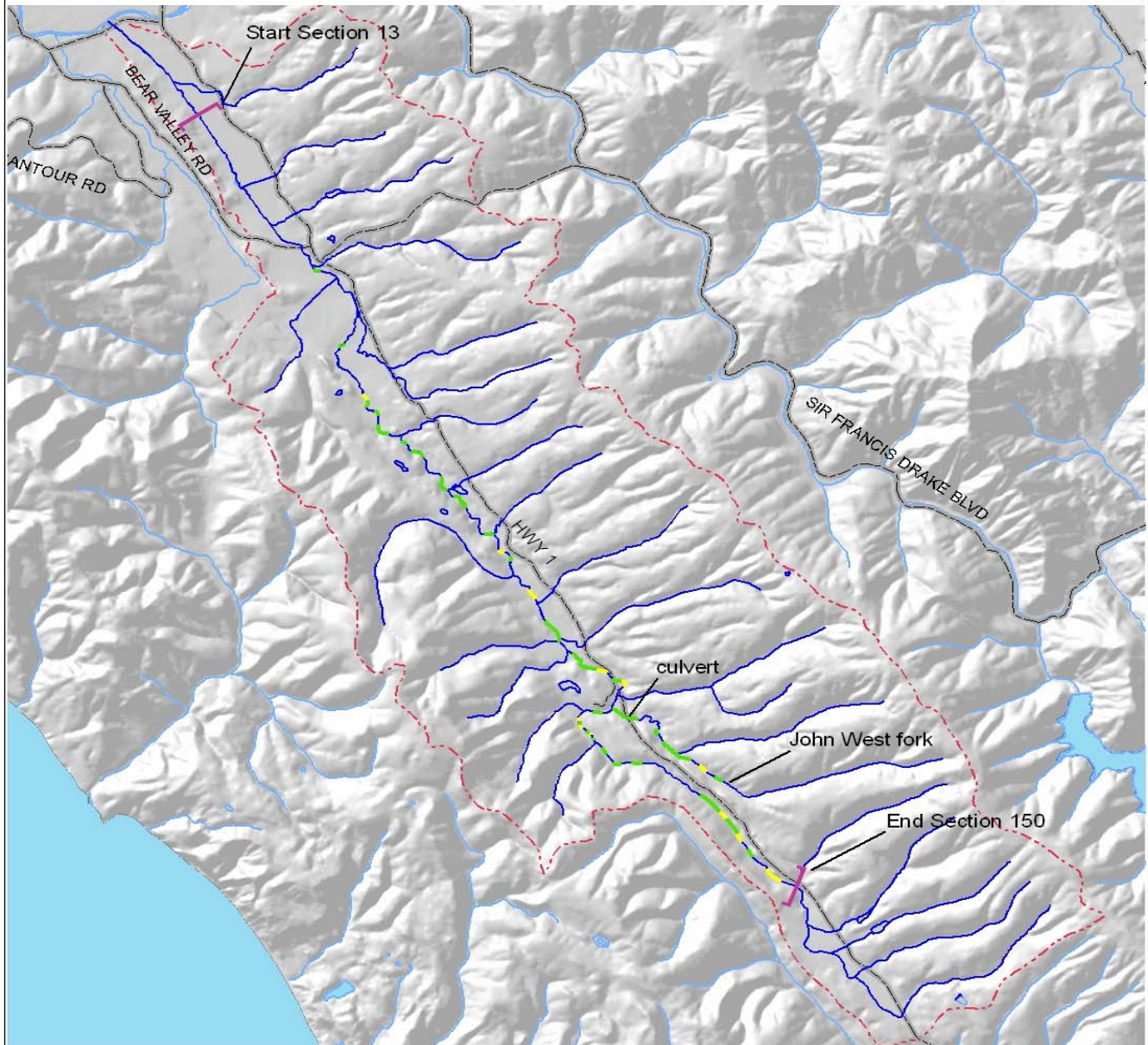


Plot date: Sept. 21, 2005 S:/GIS/projects1/Wildlife/Fish/2005\_coho\_redds

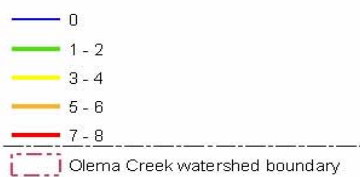


# 2003-2004 Coho Redd Density

## Olema Creek and John West Fork



### Coho redds per 100 meters



### Map Location



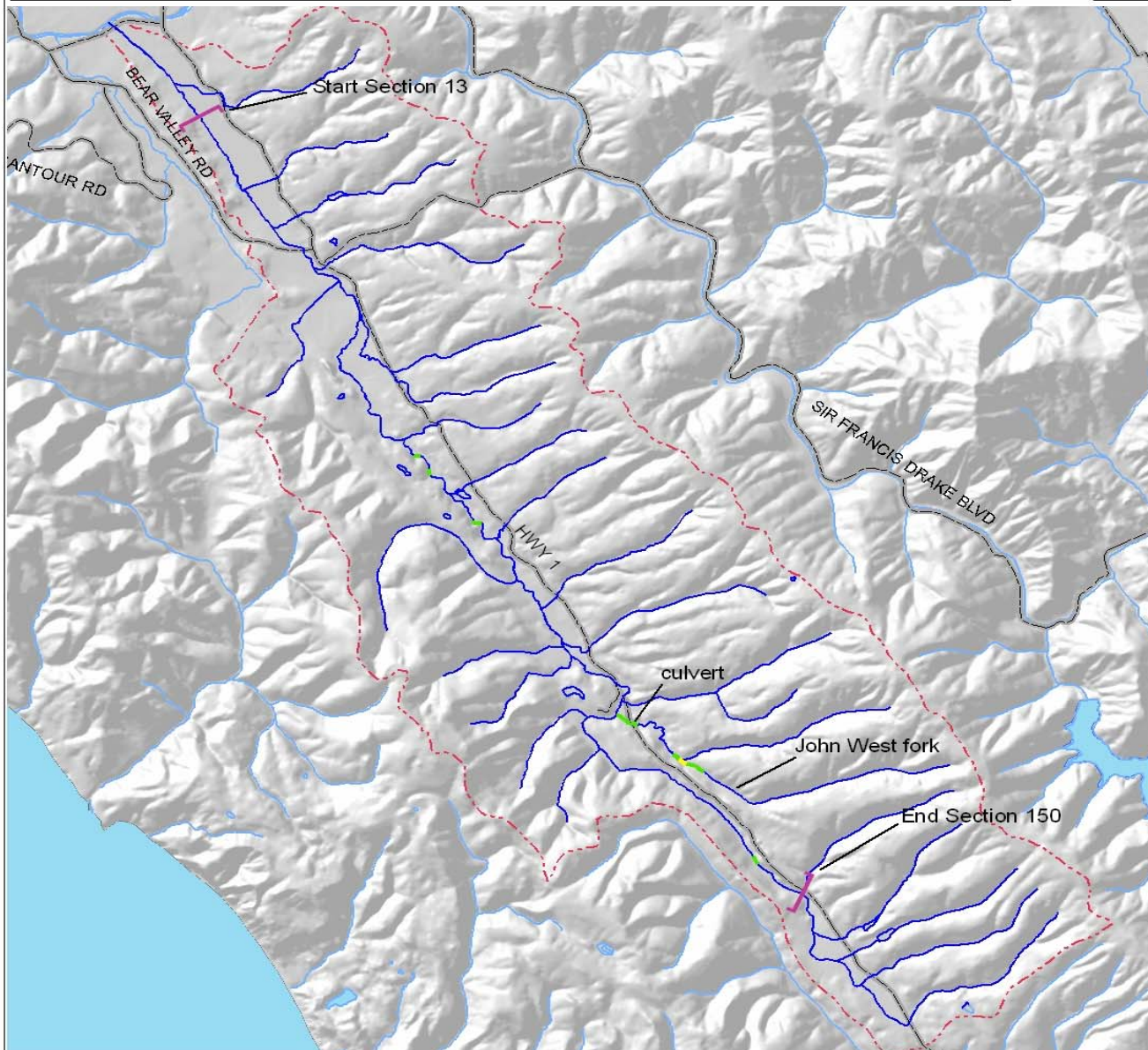
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Point Reyes National Seashore





# 2002-2003 Coho Redd Density

## Olema Creek and John West Fork



### Coho reds per 100 meters

- 0
- 1 - 2
- 3 - 4
- 5 - 6
- 7 - 8

----- Olema Creek watershed boundary

### Map Location



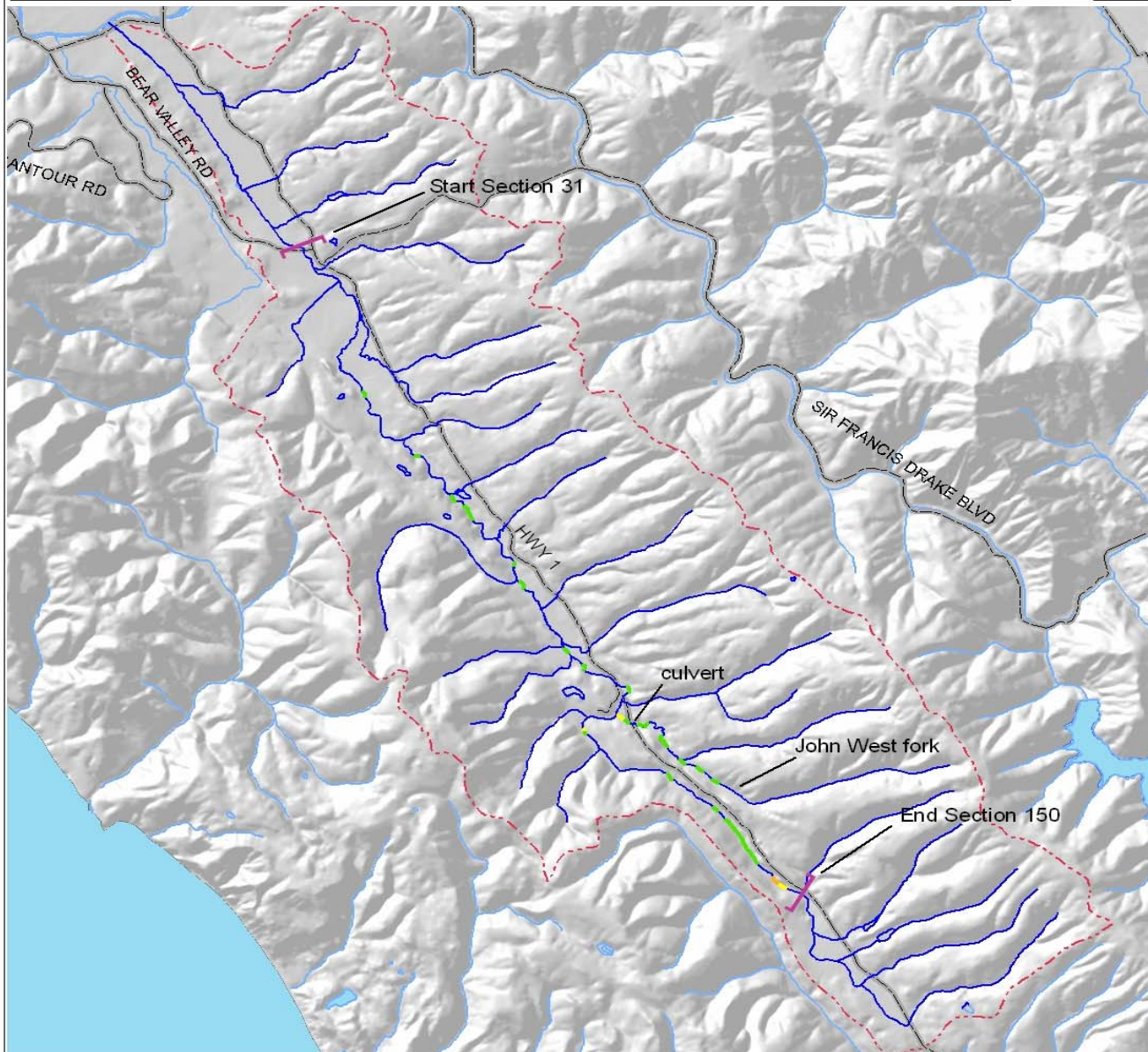
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# 2001-2002 Coho Redd Density

## Olema Creek and John West Fork



### Coho redds per 100 meters

- 0
- 1 - 2
- 3 - 4
- 5 - 6
- 7 - 8

----- Olema Creek watershed boundary

### Map Location



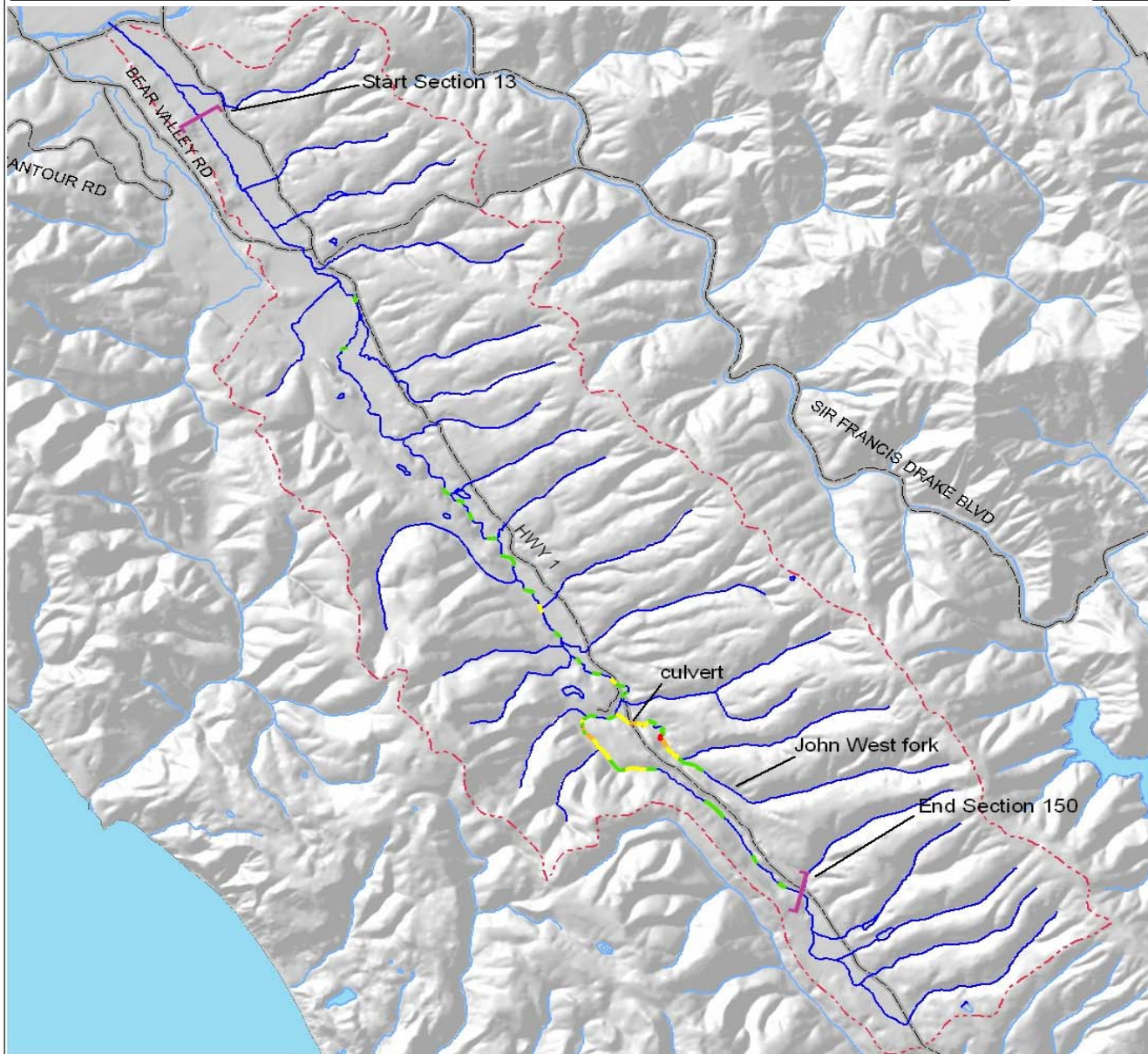
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# 2000-2001 Coho Redd Density

## Olema Creek and John West Fork



### Coho redds per 100 meters

- 0
- 1 - 2
- 3 - 4
- 5 - 6
- 7 - 8

--- Olema Creek watershed boundary

### Map Location



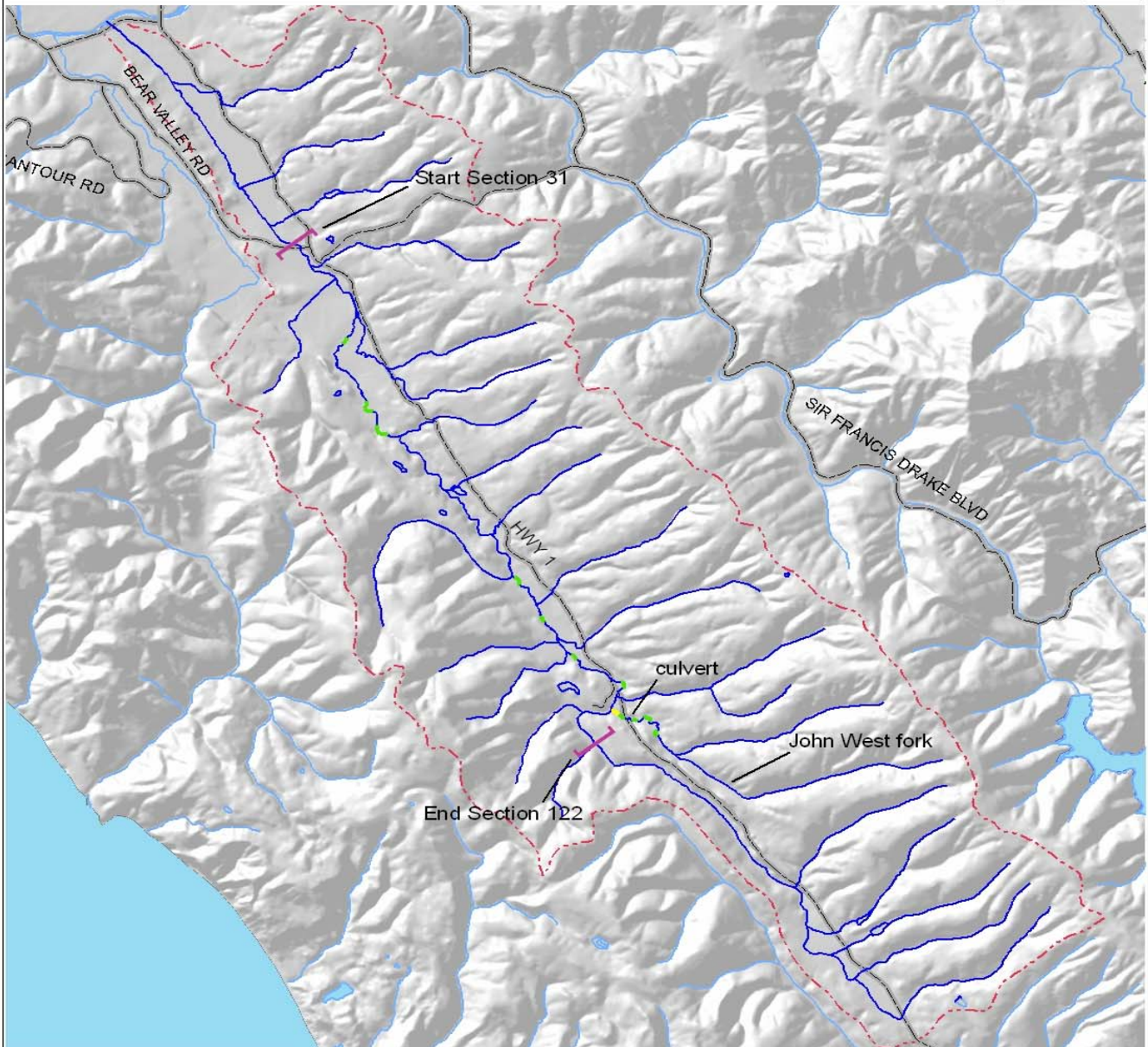
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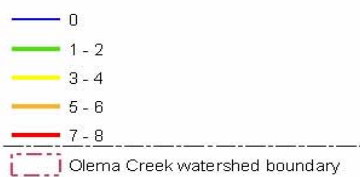


# 1999-2000 Coho Redd Density

## Olema Creek and John West Fork



### Coho redds per 100 meters



### Map Location



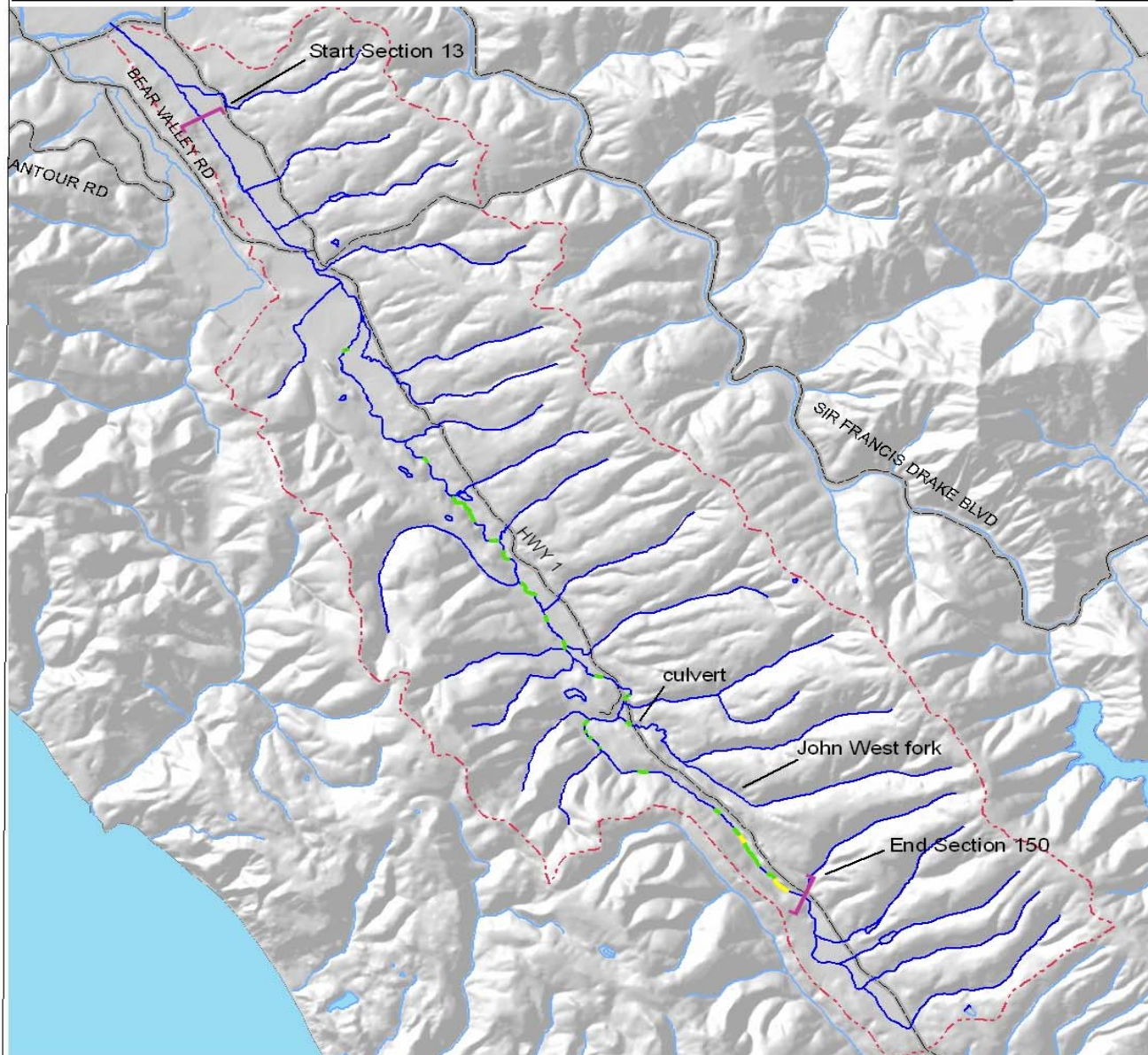
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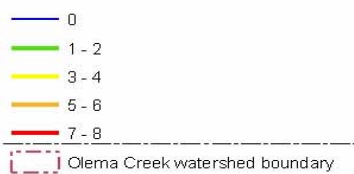


# 1998-1999 Coho Redd Density

## Olema Creek and John West Fork



### Coho redds per 100 meters



### Map Location



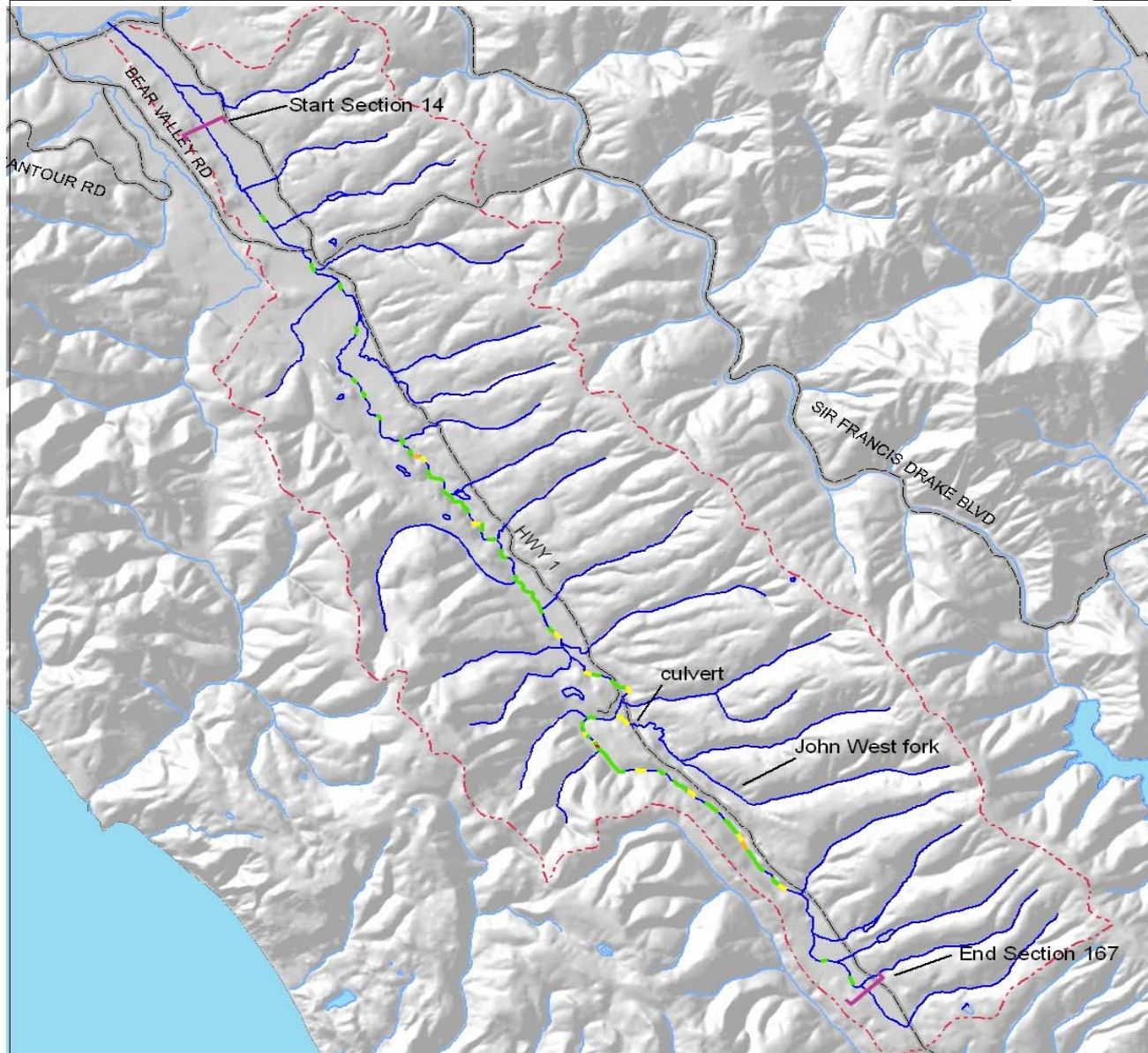
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Point Reyes National Seashore





# 1997-1998 Coho Redd Density

## Olema Creek and John West Fork



### Coho redds per 100 meters

- 0
- 1 - 2
- 3 - 4
- 5 - 6
- 7 - 8

-----  
Olema Creek watershed boundary

### Map Location



National Park Service  
Point Reyes National Seashore



